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INCREASING THE CAPACITY OF THE LOS ANGELES AQUEDUCT

By James E. Phillips

(Engineer, Department of Water and Power, Los Angeles, Calif.)

When the Department of Water and Power of the City of Los Angeles began in 1928 to seriously consider the Mono Basin as a supplemental source of water supply one of the most important problems to be solved was how to convey this water from the Mono Basin to Los Angeles. This project had been under consideration for a great many years. Records of runoff in the Mono Basin had been studied and it was pretty definitely established that there was not sufficient water in the Mono Basin to justify the expenditure necessary to construct a second aqueduct a distance of some 350 miles paralleling a greater part of the way the present Los Angeles Aqueduct.

Stream flow records in the Mono Basin indicated that a safe, dependable yield of 140 second feet of water was available from this source. Records of stream flow in the Owens Valley made and kept by the Department of Water and Power over a period of approximately 25 years and which period included several years of subnormal precipitation and runoff together with the estimated amount of water which could be depended upon from the underground basin of the Owens Valley would, in 1928, and do now, indicate the safe dependable yield of water from Owens River sources to be approximately 300 second feet. The sum total of water to be transported to Los Angeles from these two sources, therefore, would be 440 second feet.

The present Los Angeles Aqueduct, constructed during the period from 1907 to 1913, was designed and built to deliver from the Owens River Valley 400 second feet of water into Los Angeles.

It occurred to the engineers of the Department to make a study of the actual carrying capacity of the aqueduct and to determine the possibility of making it carry a mean annual flow into Los Angeles of 440 second feet. Taking into consideration the fact that the aqueduct would necessarily have to be inoperative during a portion of each year for maintenance and repair, it was estimated that to produce a mean annual flow of 440 second feet a maximum capacity of 480 second feet would have to be attained. Field investigations and studies were begun to determine whether or not it would be possible to do this within a reasonable cost; if so, the problem of transporting Mono Basin water to Los Angeles would be solved.

A force of engineers was organized to investigate and study the hydraulic properties of the aqueduct, and, during the years 1928, 1929 and 1930 at every available opportunity when the aqueduct was shut off or could be shut off, very thorough examinations and inspections were made of the interior surfaces of all tunnel and conduit sections. Measurements and notations were also made of the high water marks and hydraulic grade line throughout the aqueduct; cross-sectional areas were carefully checked; levels were run along the bottom of the aqueduct to check the constructed grade, and all hydraulic properties, including coefficients of friction, were carefully computed and checked. In order to facilitate these studies the interior surface of the aqueduct was classified according to kind and smoothness of finish, as shown in table 1.

The value of the coefficient of friction "N" in Kutter's formula as found to exist varied from about 0.012 to as high as 0.015, the average being about 0.014 which was the value adopted by the engineers who designed and built the aqueduct. An average value of "N" of about 0.012 would produce the results desired and we especially studied those sections of the aqueduct which had that value to ascertain what degree of smoothness would have to be given the surface to produce the desired results. It was believed that a smoothed, troweled plaster finish on the bottom together with a smoothing up of the sidewalls where a float finish or rougher surface existed would be all that was necessary to produce the desired results other than to enlarge somewhat those few constricted areas heretofore referred to.

That part of the aqueduct to be considered extended from Haiwee

Reservoir southerly to Los Angeles, a distance of about 190 miles. The 60 mile section north of Haiwee Reservoir did not enter into the problem as it was originally constructed with a capacity of 900 cubic feet per second, which was ample to take care of the additional water from Mono Basin. At the time of beginning our investigations the actual maximum capacity of the aqueduct from Haiwee Reservoir to Fairmont Reservoir, a distance of about 125 miles, was 410 cubic feet per second and the maximum capacity between Fairmont Reservoir and the City of Los Angeles was 450 cubic feet per second. These limiting capacities, however, did not apply throughout the entire length of the aqueduct. Many places, especially the steel

TABLE 1

CLASSIFICATION NUMBER	DESCRIPTION
1	Plaster
	a. Very smooth
	b. Smooth
	c. Rough
	d. Brushed plaster
2	Concrete formed with steel forms
3	Concrete formed with wood forms
4	Float finish
	a. Smooth
	b. Rough
5	Gravel
6	Rock
7	Grout
8	Gunite

siphons and many of the tunnels, indicated that they would, under the then present conditions, carry up to as much as 500 second feet. These facts were determined from our preliminary studies, and the fact that some sections were capable of carrying 500 second feet encouraged us to believe that a capacity of 480 second feet throughout the entire length of the aqueduct was not impossible. It was a matter of determining what the causes were which limited the flow to 410 second feet. Some constricted areas were known to exist where emergency repairs had been made and where time was not available to reconstruct the same with full cross-sectional areas. These few places, of course, could be easily enlarged to a full section.

When all the data relating to the hydraulic properties and condition

of interior surface were assembled and correlated it was quite definitely established that the problem was one of decreasing frictional losses and that by smoothing the bottom and sidewalls of certain sections a capacity of 480 second feet could be obtained and the work done at an estimated cost of about $600,000.00. This seemed a very reasonable cost for transporting 140 second feet of water for 250 miles of the total distance between Mono Basin and Los Angeles. Money was made available for the entire project by the bond issue of $38,000,000.00 voted by the City of Los Angeles in 1930 for an additional water supply and for the enlargement of the storage and distribution facilities.

REFINISHING THE INTERIOR OF THE AQUEDUCT

Preparations were made for starting the work in the fall of 1930. The operation of the aqueduct required that the work be done in short working periods of twelve to fourteen days each during the winter months when the demands for aqueduct water were at a minimum. Four periods during the winter of 1930–31 and one period in the early part of October, 1931, totaling altogether 66 working days, have, so far, been available for actual performance of the work. In addition to the work for increasing the capacity of the aqueduct it was also proposed to take advantage of the several shutoffs to do considerable deferred maintenance work, especially in tunnels where excessive earth pressure and ground movement had damaged the sidewalls and arches.

The program as outlined embraced the following operations:

1. Resurface where necessary the bottom of tunnels and conduits with cement and sand mortar, varying in thickness from $\frac{1}{2}$ to $\frac{3}{4}$ inch.
2. Refinish sidewalls of tunnels and conduits where necessary by either plastering, painting or grinding.
3. Enlarge such sections as were considerably under size. (These were of minor importance.)
4. Clean and paint the interior of all steel siphons.
5. Repair sidewalls and arches of tunnels by reinforced concrete stabilizing rings and by grouting.

In the performance of the refinishing work two things were of major importance. The finished surface must be extremely smooth and extremely hard. We found that it was easy to accomplish either one of the two but their combination presented more of a problem.

All existing data on the subject of concrete finishing was studied and made use of, but it must be recalled that the conditions under which we were forced to work were anything but ideal. In tunnels, especially, the material had to be hauled long distances underground; space in which to work was confined within narrow limits; presence of water in the tunnels and its action on the finished work had to be coped with; the problem of finishing the surface and preventing damage to the same by workmen until it was finally set up had to be worked out; and other conditions affecting the time of setting of the cement, all tended to make it a problem not usually met with where the work is out in the open and the question of handling material and men is not such a handicap.

The question of proper mixing of the cement mortar to be used probably received more consideration than anything else, not only in the proportion of cement and sand, but more especially in the quantity of water to be used in the mixing. Continuous tests were made of the water content of the sand used and the quantity of mixing water added at the mixer was carefully measured and checked. Concrete mixers were equipped with meters to measure accurately the mixing water and the mixer men were particularly instructed and watched in this regard. It was also found that the manner of placing the mortar and its handling as regards spreading and troweling were very great factors in producing an extremely hard finished surface.

It seemed advisable in the beginning to do considerable bottom resurfacing and determine the results of this before doing much refinishing of sidewalls. Opportunity, however, was taken during the earlier periods to experiment with the latter to determine the best method of procedure. This proved to be a wise decision as such splendid results were obtained by the bottom resurfacing alone that it has been found unnecessary to do much sidewall work except where unusually rough. The method found most practicable and producing the best results as regards durability and smoothness for the resurfacing of sidewalls seemed to be a very thin neat cement mortar troweled smooth and then brushed with a fine hair brush.

During the 66 days that the work has progressed, 250,000 lineal feet, or approximately 50 miles, of aqueduct bottom have been resurfaced. The average bottom width is 10 feet. The sidewalls of about 5 miles of the aqueduct have also been refinished. Practically all of the maintenance and repair work in tunnels has been completed and three or the steel siphons have been cleaned and painted. An

average of about 600 men were employed on the work, and the total cost to date of the work directly pertaining to increasing the capacity is approximately $380,000.00.

As a result of the work so far performed, I am happy to state that during a test conducted a few days ago, a three-day sustained flow of 480 second feet of water was passed through the aqueduct from Haiwee to Fairmount Reservoirs without taxing its capacity at any point.

(*Presented before the California Section meeting, October 29, 1931.*)

OBSCURE GASTRO-INTESTINAL OUTBREAKS ASCRIBED TO WATER SUPPLY

By Carl Wilson

(*Director of Sanitation, Department of Water and Power, Los Angeles, Calif.*)

Since the adoption of the Treasury Department standard for bacterial quality of water, and more particularly since chlorination of public supplies is all but universally practiced, the water works official has naturally come to believe that a colon-free water cannot possibly transmit disease. Perhaps he is right, but in view of recent happenings it seems only judicious to investigate carefully the possibility of his confidence being in part misplaced. Apparently there can be no doubt that typhoid fever, Asiatic cholera, and the dysenteries cannot be carried by water which continuously fails to show the presence of colon bacillus, but is this equally true for all the infectious diseases to which human flesh is heir? Is it possible for the germs of diseases not yet recognized as being water-borne to gain access to and persist in our water unaccompanied by colon bacteria and so escape detection by our present methods of testing water?

Explosive outbreaks of gastro-intestinal disorders, ill-defined in character, have been reported from many localities in all sections of the United States and there is a strong tendency throughout the lay-population, only too often shared by health officials in the absence of proof to the contrary, to incriminate the public water supply. All these outbreaks have been short-lived, and recovery of individual patients is so rapid that medical aid is seldom invoked, and little or no laboratory investigation has been possible. The characteristic symptoms have been nausea and violent vomiting, generally without a rise in temperature, and only occasionally accompanied or followed by diarrhea. Weakness approaching exhaustion frequently follows the vomiting, which may continue for several hours, and recovery is usually complete in 48 to 60 hours.

Some of the recent California outbreaks may be listed as follows:

Eagle Rock: Investigated by Los Angeles Health Department and the writer.

Santa Ana: No special investigation.
Carmel: Investigated by County Health Officer and writer.
Santa Paula: Investigated by Local, County and State Health officials and the writer.
Arrowhead Lake: Investigated by California State Department of Public Health.
Pacific Palisades. Investigated by writer.
Independence and vicinity: Investigated by State Health Department.

EXAMPLES OF GASTRO-INTESTINAL DISTURBANCES

The Eagle Rock cases were confined to pupils of the San Rafael Grammar School, but approximately 200 of the 300 children enrolled were ill. About six children went home ill the first afternoon, and 175 or more were attacked the second day, with four or five new cases the third day. The explosive character of the outburst is unusually evident, and naturally water and milk were at once suspected. Milk was quickly eliminated, and the City Health Department investigators brought in a report laying blame upon the municipal water supply. The writer submitted a report for the Water Department in which he pointed out what he considered conclusive proof to the contrary, viz.: that all the Eagle Rock area as well as a large section adjacent is served by one water, entering the district through a 30-inch trunk main, but that the outbreak was confined to pupils of one school district, representing perhaps 5 per cent of the residents of Eagle Rock. The water is derived from the underground flow of the Los Angeles River, and is well protected. It seldom shows the presence of colon bacillus, but is continuously chlorinated as a precautionary measure. The second day of the outbreak the writer installed an additional chlorine machine at the Eagle Rock end of the transmission main and operated it continuously for several months as a matter of policy rather than conviction. Daily bacterial samples in Eagle Rock showed the supply to pass the Treasury Department standard. The Health Department report was never published. No tenable explanation of the outbreak was ever reached.

Concurrently with the Eagle Rock flare up there were a great many cases of similar type in Santa Ana, but residents of that city, still remembering the recent typhoid epidemic, calmly condemned the water as responsible for this, as for every other ill, and promptly forgot the matter. No investigation of this situation was made, except for a few inquiries by the writer to confirm the existence of the malady.

At Carmel, using a surface water which is stored for several months and chlorinated as it enters service, there were over a hundred cases, all developing within a week. Local physicians called in the County Health Officer, who made a careful study of all factors, but without being able to find the cause. The water was examined in different laboratories but no proof of its pollution was found.

At Santa Paula there were said to be some 700 cases, distributed rather evenly over the city except for the fact that the Mexican population escaped almost completely. The water supply was scrutinized from every angle, and one reservoir, which showed a colon index slightly higher than the generally accepted standard, was thrown out of service the second day of the outbreak, while chlorination of the entire supply was increased to the point of taste. The unanimous opinion of all investigators was that no proof against the water could be found, yet there was left in the minds of many people the feeling that in some unknown way the water was really responsible for the illness. In fact, several public health officials of the writer's acquaintance still hold and voice this opinion.

The Pacific Palisades outbreak included only ten cases, in three different families, and could not be tied to the public water supply. It is mentioned only to emphasize the tendency of the public to lay the blame for any outbreak of infectious disease upon the water supply. Perhaps we have to thank bottled water salesmen for this situation, for it is undoubtedly true that their incessant efforts during the last ten years have made all Californians extremely "water-conscious." A prominent newspaper man (not a cub reporter) took up the cudgel to fight for the rights of the down trodden and to compel the water department to serve safe water. It took several hours explanation to satisfy him that he was not justified in making a newspaper campaign against careless officials, but when no more cases developed he was subdued.

POSSIBLE CAUSES

The water works man will not be recognized as blameless until the cause of such explosive outbreaks has been discovered and conclusively proved, and he owes it to himself and his consumers to secure such proof at the earliest possible moment. What can he do?

Before we can attempt to answer this question we must consider the apparent possible causes of such illness. First we suspect B. enteritidis of Gaertner, or the bacillus of meat poisoning, for it can

produce these symptoms, and in light dosage might manifest no others. Can enteritidis remain alive and virulent in water, and how could it gain access thereto? It has been suggested to the writer by a prominent health official that this organism might proliferate in our mains under dead-end conditions if the water contained sufficient organic matter, and there elaborate enough toxin to affect all water consumers within a limited area, particularly if syphonic action, due to reduced pressures, should mix the dead-end water with live water in the mains. The objection to this is that most bacteriologists do not believe the Gaertner bacillus would ever multiply sufficiently in such an environment to be of pathologic significance. However, the possibility should be proved or disproved by laboratory investigations.

The next suggestion is that the malady is due to the activity of haemolytic streptococcus types of bacteria, but those health officials who adopt this view admit in the same breath that these organisms are milk-borne, and probably never water carried. From a purely selfish viewpoint, let us hope they may be correct, but our work will not be finished, nor our water freed from suspicion until conclusive proofs have been adduced.

Another theory, also advanced by public health officials and epidemiologists, is that pollen from certain trees, particularly pines and tamaracks gain easy access to our waters, and when they enter the human body function as foreign proteins, giving rise to the gastro-intestinal symptoms. This is an interesting possibility, and capable of experimental proof. Every possible effort should be made to test this theory. It must be admitted that such pollens could easily enter the water at Carmel, at Santa Paula, Arrowhead Lake, and even at Independence, but not at Eagle Rock, Santa Ana, or Pacific Palisades.

The writer believes pollen would not pass through a large impounding reservoir because it would become water-logged and settle out enroute, but that it might be a factor in small supplies diverted from mountain streams and used without storage or treatment. Thousands of plankton samples which have been examined in the Los Angeles Water Department laboratory during nearly twenty years have certainly failed to show the presence of pollen cells in stored waters.

We are forced to admit that the question is unsettled, although we like to believe our waters not culpable. The real cause must be found, and it would be wonderful if the water works profession could

cooperate in the establishment of an organization to carry on such research investigations, much as chlorine manufacturers maintain the Chlorine Institute to conduct needed research. In the meantime every water works man, particularly those interested in water purification and treatment, should watch for similar outbreaks in this area, and should they appear he should make it his business to see that competent epidemiologists from his local Health Department or from the state thoroughly investigate the cases. He should see that stools from patients are taken promptly and sent to a laboratory for diagnosis, looking especially for B. enteritidis Gaertner and streptococci. He may have to incur some personal inconvenience to accomplish this, but he will perform a real service to humanity and to his profession, and he certainly owes it to himself to aid in solving the problem, for in no other way can he completely rid himself of suspicion.

Certainly, he should be the first to admit the need of carefully considering any evidence, however inconclusive it may seem to be, that his water may be the vehicle of disease. If his product is a menace to his consumers he will gladly welcome proof of the fact, so that he may provide adequate safeguards and may be counted upon to approach the problem with an open mind.

The Mills-Reincke phenomenon showed us that substitution of pure water for a contaminated supply always causes a reduction in death rates beyond that which could be accounted for by the drop in typhoid. Allen Hazen gave a numerical value to this statement when, as a result of his studies, he said that where one death from typhoid was prevented, two or three deaths from other causes were also prevented. The causes of these additional deaths seem to bear no relationship to colon bacillus, and this seems to suggest that absence of intestinal bacteria is perhaps not complete proof that our water is safe in all respects.

DISCUSSION

The above remarks were sent to several sanitarians, bacteriologists and epidemiologists, and the following comments offered by them are added as the most valuable part of the paper.

Dr. K. F. Meyer, Director of the George Williams Hooper Foundation for Medical Research, at the University of California, states:

The paper presented by Mr. Wilson is exceedingly timely. For years water-borne gastroenteritis has been observed and on account of its similarity to food poisoning, has attracted the attention of numerous workers. Unfortunately no definite causal agent has as yet been satisfactorily determined. Painstaking studies by Jordan and Yron failed to elicit the cause of the water-borne "food poisoning" epidemic which involved 10,000 people at Lockford (Illinois) in 1912, in a population of 50,000.

I doubt if the B. enteritidis Gaertner would ever play a rôle. It is a strict parasite and is relatively rare even in well proven cases of food poisoning in which veal or beef is the vehicle of the infective agent. Equally uncertain is the hemolytic (?) streptococcus. The toxin produced by the organism rarely acts on the intestinal mucosa when introduced in a non-protein medium. In recent years suspicion and, in fact, conclusive evidence, incriminates the staphylococcus group as producers of a toxin which severely irritates the intestinal canal and may induce all the symptoms so characteristic for food poisoning. How this organism would elaborate the gallons of poison which may be required to induce the many thousands of cases is rather difficult to visualize. Then again it is by no means clear how these cocci would enter the water supply since they are relatively rare or absent from the human or animal excreta.

The observations by the New York State Health Department that representatives of the B. cloacal group may generate a poisonous irritant for the intestinal mucosa deserves, however, careful consideration. There is no doubt that the type of outbreak as mentioned by Dr. Wilson is of bacterial origin. The bacteriologist usually arrives at the scene when the water has already freed itself of the pollution or poison, and an examination, careful and thorough as it may be, will reveal nothing, not even a lead. Many of the epidemics are only reported several days after the peak has passed. House to house canvass investigations are then considered unnecessary. A modern epidemiologic intelligence service demands a thorough collection of the facts, a statistical analysis of the data and a deductive, etiological inquiry. According to my experience these principles have not always been fulfilled in the attempts to solve a problem which deserves the wholehearted attention of the American Water Works Association. Clinician, bacteriologist and water engineer must work together and must penetrate the emotional, non-objective "smoke screen" which usually surrounds the early days of an extensive, expensive epidemic.

Dr. R. V. Stone, Director of Laboratories for the Los Angeles County Health Department says:

Many things besides water should be a part of the history of a suspected water-borne epidemic. School cafeteria conditions, transient venders of ice-cream cones, hot dogs, etc., certainly should be ruled out on school epidemics before incriminating the water too definitely. If this was done in the case of the Eagle Rock epidemic I believe it should be mentioned.

The exoneration of a water supply as a cause of acute gastro-intestinal disturbance definitely is hampered when we consider the Santa Ana typhoid epidemic of a few years ago. Published accounts of this epidemic bring out the fact that several thousand persons left their business hurriedly because of an acute intestinal disturbance, but it was purely transitory and far in excess of the typhoid cases that developed later. In the mind of the commentator this would indicate that the sewage contaminated water carried not only typhoid organisms, but also a gastro-intestinal irritant which may have been a toxin but which in any case was incapable of implantation in the human body.

The episode of the difficulty in Ventura County registered in the minds of Health Officers, probably in part due to newspaper accounts setting forth as a cause the presence of flies or larvae in the water supply. This was so revolutionary a postulation of the cause of acute gastro-intestinal disturbance as to not be soon forgotten. Later persistent rumors implied that a Mexican picnic was held adjacent to an open stream which formed a part of the source of the water and the population (white) was affected by certain careless practice of the picnickers. This would in part explain why the epidemic hit the white population and missed the Mexicans.

So far as enteritidis is concerned I personally feel that we should not take the matter of dead-ends into consideration seriously. It is very apparent that enteritidis is not over prevalent even in our food poisoning cases where cultural conditions for the propagation of this organism are certainly more ideal than any water supply. We might venture to point out the existence of steam tables and other contrivances at barbecue stands, etc., where meat is not only kept at a favorable incubation temperature, but also frequently the handling of such food and exposure to highway conditions would seem to predispose to contamination of that food.

The pollen epidemic theory does not seem to be logically con-

sidered by various commentators inasmuch as many vacationists in highly potential (as to pollen) areas experience no difficulty. We can consider the High Sierras as an example. I see no reports of difficulty in the areas such as Tuolumne Meadows with a definite heavy pine tree condition, yet there have been cases reported year after year in the Sequoia National Park area on certain flats removed from the Sequoia trees and restricted to pine trees. When these epidemics occur they occur in mass as epidemics rather than as sporadic cases and since the vacationist is present annually in about the same numbers in the same areas under the same conditions, we would certainly expect a very definite seasonal time of expectancy, but this is not the case. I believe your comment in regard to pollen becoming water-logged and settling out is well taken.

We are bound to form certain opinions through experiments and through analogy and since the relatively recent work on staphylococcus and streptococcus in poisoning has come to light I have been more and more impressed with the similarity between the so-called water-borne acute gastro-intestinal disturbances and food poison epidemics due to staphylococcus and streptococcus. These include:

(a) Rapid on-set with vomiting and diarrhea, this occurring within a few hours from the time of the consumption of the contaminated substance.

(b) The rapid recovery which usually is within twenty-four hours from the time of onset.

(c) The feeling of prostration after recovery which seems to be very common and very short in its effect.

We know by experimental practice that the staphylococcus and streptococcus toxin (?) can be filtered through Berkfeld filters and still manifest its gastro-intestinal disturbance in kittens. As a matter of fact, Jordan in Chicago has run conclusive tests on human volunteers and finds that the condition is quickly induced on such persons. We further know that these filtrates can be boiled and the cultures can be boiled and will still manifest their influence. We further venture the opinion that we have not subjected to test, that chemical treatment such as chlorine would not render this substance impotent. Taking this matter into consideration in a theoretical conclusion, I believe that this could happen—that sewage could enter a water supply which was normally chlorinated regularly in quantities sufficient to destroy bacterial organisms including the colon bacillus, and yet, nevertheless, an irritating substance would be capable of involv-

ing a whole community or a part of that community that received a heavy dose of this chemically sterilized sewage polluted water.

It has been shown rather conclusively that in food poison cases immunity is not produced. We have repeatedly exposed the same kittens to sterile filtrates at weekly intervals and produced severe gastro-intestinal disturbances each time the kittens had tests conducted. I venture the opinion that if we had accurate records we would find that humans who were involved in a so-called water epidemic of this nature would be susceptible to a subsequent exposure. Generally speaking, there is so much yet to be known about these disturbances and about organisms that produce this irritating substance that we must reserve a conclusive statement until such time as we have been able to obtain the experimental proof. It is regrettable that a research institution such as you have mentioned is not available to fill in the gaps of our knowledge. Thousands of dollars would be necessary to properly conduct this work, but no matter how great the expense, definite facts obtained would undoubtedly justify the complete expense even if assigned to but one city, due to the fact that future generations of that city would have a definite protection.

R. B. Durfee, M.D., Superintendent of Public Health of Cochise County, Arizona, brings a word of cheer for the water works man. He says:

The tendency of the general public to blame water for all sudden outbreaks of gastro-intestinal diseases has probably survived from the old days, when water supplies were not adequately protected, and were more or less at fault. With modern methods of water treatment the water works official should have full confidence in the integrity of his water supply, and should pass this confidence on to the general public. While it is possible, even probable, that in the future some water-borne disease will be discovered of which we now have no hint, at present the finger of suspicion should not be allowed to be pointed in our direction without vigorous protest.

Research has clearly shown that B. coli is the most resistant of all forms of vegetative bacteria to chlorination, and that if a water supply is chlorinated sufficiently to kill B. coli all other forms of vegetative bacteria are also killed, including Gartner's Bacillus and the Cocci. If it were possible for formation of toxin above the point of distribution, dilution would be great and the outbreak prolonged. As these water supplies were properly chlorinated and the integrity

of the distributing systems beyond question, there is no possibility of the water being at fault.

In considering these outbreaks there are questions which should have been answered by careful epidemiological study, but were not. Why were the San Rafael School children affected and not others receiving the same water? Did the two hundred ill children drink water at the school and the one hundred well ones refrain? Was something eaten at the school by the ill and not by the well? Was illness due to poison, toxin or bacterial invasion, and if bacterial invasion what was the organism? Why should the Mexicans at Santa Paula not have been affected as well as the whites?

The symptoms of acute nausea, vomiting, particularly marked exhaustion, little or no diarrhea, with explosive violence of onset, and illness of short duration, have all the earmarks of food poisoning. There is no doubt but that if efficient epidemiological effort had been applied to the study of these outbreaks, such a diagnosis would have been made. There is no evidence offered which would incriminate the water supply.

The question is, as far as the water sanitarian is concerned, will he have to enter the field of epidemiology for his own protection?"

C. S. Gillespie, Chief of the Bureau of Sanitary Engineering, California Department of Public Health, says:

At Carmel I think you could go even stronger and say that there was not only no proof of pollution but no history of an occurrence whereby pollution might have taken place.

At Santa Paula this was not quite the case. There was a lack of laboratory analyses just prior to the outbreak and hence no proof of pollution, but there was the history of a Mexican picnic two days before the outbreak in which several thousand people were picnicking along the edge of the creek 1500 feet or so above the intake, and there were only two privies for this whole crowd. The only concrete report of sewage contamination of the creek was that a Mexican woman washed diapers of a couple of twins in the creek water. Furthermore, though it seems the Mexican population did not come down with the outbreak at the time the white population did, reports were current that the Mexican population had been bothered with this kind of an ailment for the previous three or four weeks, and it may be a lot of carriers were developed and with a high degree of immunity in the Mexican contingent.

There have been a great many other epidemics of this same sort. I think of one particularly pronounced at Corning where the water was from wells. It happened a sewer line ran through the box housing one of the wells, but there were no indications of escape of sewage out of the sewer line. The water did not show pollution by tests. Therefore, this outbreak is another one of these obscure propositions.

A small outbreak occurred at Winters. From time to time we get reports of small scale outbreaks that sound much the same. My impression, however, is that quite universally there is diarrhea associated with these outbreaks and an element of prostration runs through all that I have ever had anything to do with. Of course, I think it does not follow that there is any one cause or one organism, if it be an organism, that explains these outbreaks.

CHARLES GILMAN HYDE, Professor of Sanitary Engineering at the University of California, says:

I have read your paper with the greatest interest and I really have no comments to make except, possibly, that the Hazen Theorem and the Mills-Reinke Phenomenon seem to apply only to those cases where a good supply has been introduced to supplant an exceedingly polluted source. The results which you have stated do not seem to obtain except with an extraordinary change from bad to good.

In connection with your discussion you might be interested in the following memoranda with respect to a sudden infection due to an unknown organism which occurred in the City of Alameda in 1909 when that town had a population of about 22,000.

On Friday night, February 12, 1909, the cases began to come down and the onsets continued until Sunday, February 14, by which time 38 percent of the population of the city was affected. The patients had severe nausea with spells of vomiting, showed slight fever and had more or less pain in the region of the abdomen. The disorder was marked by excessive diarrhea for at least 24 hours and this was continued for a greater length of time if purgatives were taken. Few cases were attended with serious after effects. Persons with weak constitutions or those who were sick with other diseases had aggravated cases of this disorder.

A typical case was that of a young man from San Francisco who was in Alameda dining with friends during only a few hours on the evening of February 12. In the early evening he returned to San Francisco. About midnight he was seized with nausea and diarrhea

but after about 24 hours he was completely recovered and suffered no apparent after effects.

In studying this epidemic 414 houses were visited in which there were 1671 residents. Among this number there were 638 cases. The houses visited were scattered uniformly throughout the 13 wards of the town.

Careful inquiry seemed to reveal no other possible source of the infection than the water supply, although it is difficult to conceive how any bacterial infection could become active in so short a period after ingestion of the water. The Water Company first heard of the epidemic on February 14 and immediately shut off the Fitchburg well system which had been supplying the city with water for the most part. These wells had been overflowed with surface water resulting from severe storms; also, with bay water driven through breaks in the levees by storms. The casings of the wells were in bad condition. Routine samples of water collected on February 8, 15 and 20 showed no B. coli in 1 cc. and only one sample was positive in 10 cc.

C. W. Decker, M.D., Health Officer for the City of Los Angeles, says:

Your review of some recent studies of gastro-intestinal disturbances attributed to water is most interesting. Many of the fantastic theories advanced by the press are not commented upon. The public who see the papers usually do not have access to correct information.

Our investigations led us to believe that the Eagle Rock and Pacific Palisades outbreaks might be gastro-intestinal irritation from decaying vegetable matter. At Eagle Rock, especially, there was a history of some disturbance of the water supply flushing a water main, or cleaning a storage reservoir, I am not sure which, that seemed a possible source of the trouble. We believe that the sediment was stirred up and not sufficiently washed out, and then entered the drinking water. I am writing this from memory without access to our office records and hope you will forgive me if some of the events are not exactly in accord with your own history.

There is plenty of room for study along lines you suggest and colon bacilli, while important as an index, should not deter us from search for other causes of disease in water. Your article is timely and should lead to better understanding as others take up the investigation of these sporadic outbreaks of gastro-intestinal disorders.

JOHN F. KESSEL, M.D., Professor of Bacteriology at the University of Southern California School of Medicine, says:

The questions raised by Dr. Wilson with reference to the development of acute gastro-enteritis arising from water supplies are equally important in the field of "food poisoning" and it seems probable that the two fields have several points in common. The point of view with reference to the cause of acute gastro-enteritis, now commonly called "food poisoning" has shifted rather rapidly within recent years. There was a time when the word ptomaine was used to explain all such disturbances. It was soon found, however, that such compounds when formed were either non-toxic to the human body or else were not taken into the body in sufficient quantity to cause poisoning. With the discovery of *Salmonella enteritidis* and *S. aertrycke*, and other organisms of the same group, it came to be the custom to employ the term "food poisoning" and to explain all outbreaks in terms of actual infection with bacteria. Living organisms could be recovered only from some thirty percent of such outbreaks and another explanation became necessary which is the one coming into prominence at present.

This concludes that these acute conditions are commonly caused either by infection with certain organisms which produce within the body a thermo- and chemostabile poison or by eating cooked food in which these organisms have been growing—the potent toxin not being destroyed by the cooking. The varieties of bacteria responsible for such conditions appear to be rapidly increasing, reports of investigators having incriminated the following genera:—Salmonella, Aerobacter, Proteus, Streptococcus, Staphylococcus.

When an acute gastro-enteritis is thought to be traceable to a water supply it would appear imperative that the situation be adequately investigated in the same manner that food poisonings are studied.

When the various organisms listed above or their toxins, and perhaps additional unsuspected ones, have been eliminated then other theories should be investigated.

(*Presented before the California Section meeting, October 27, 1932.*)

TASTE AND ODOR CONTROL ON PENNSYLVANIA WATER SUPPLIES

By Howard E. Moses

(*Assistant Chief Engineer, Pennsylvania Department of Health, Harrisburg, Pa.*)

Anything that interferes with the orderly production of public water supplies is a matter of moment to the water-works man and likewise of interest to the health official because of its possible effect on public health. These occurrences vary from the minor interruptions, more or less to be expected and capable of prompt adjustment, to the catastrophe, which puts the system completely out of service. They may be merely physical in their nature, such as broken mains, or they may be of more serious import from their effect on the health of the consumers, as a disease-infected supply. Somewhere along the line, but very definitely a matter of importance, lies the occurrence of tastes and odors in public water supplies.

Of themselves, tastes and odors may not be productive of disease, yet it is possible that the causative agents may be responsible for outbreaks of intestinal disorders among water consumers. The drought of 1930–1931 gave rise to speculation as to the possible toxic effect of river supplies, depleted in volume, with heavy pollution load, and characterized by the so-called "river taste" frequently spoken of in the literature of that time. A change from one water supply to another often temporarily affects the alimentary tract. This is frequently experienced in changing from a soft to a hard water and vice versa. It is not unreasonable, then, to expect that the presence in public water supplies of substances ordinarily absent therefrom may disturb the normal functions of the body.

Be that as it may, people do not like bad tasting or bad smelling water and look upon it with suspicion, even though it is bacterially safe. Unpalatability in a public supply frequently drives the public to the use of miscellaneous supplies, palatable, but ofttimes of uncertain or even dangerous quality. This practice is a familiar one to experienced health officials everywhere.

From an opinion given to a former Secretary of the Pennsylvania Department of Health by the Department of Justice, the following pertinent statements are quoted:

"It cannot be questioned that an abundance of water must be consumed by every human being for maintaining his health and that any action or neglect which reduced the quantity available to him beyond a certain point would impair his health. The case presented by you is one where the quantity available to him is not absolutely reduced, but is made so offensive that many persons will not drink the quantity required for the maintenance of health. I am of the opinion that this is in effect a reduction of the quantity of available water necessary for the maintenance of public health.

"The law deals with men as they are. It is true that any man could force himself to drink of the offensive water enough to maintain his health, but if as a matter of fact the great majority of men, or a large number of them, will not do this, but will either reduce the quantity they drink below that required for health or will resort to unknown and potentially dangerous sources of supply, the public health will be injuriously affected. . . ."

Consequently, methods of control of tastes and odors have, in the past, and will be, increasingly in the future, a subject of interest to those concerned in the production of satisfactory water supplies.

KINDS OF SUPPLY

In large proportion Pennsylvania's public water supplies are secured from surface sources; rivers and their principal tributaries, smaller streams, and to a limited extent, from ponds and lakes. Underground supplies are used, but to a far lesser extent. Notable exceptions are the spring supplies of Allentown and Bellefonte and the wells of Meadville and Vandergrift. The river supplies are subject to pollution by sewage and industrial wastes, the latter a dominant factor in some parts of the State. Coke works, gas works, steel mills, glue works, packing houses, oil refineries, paper mills, milk product plants, textile mills, tanneries, dye works, canneries and anthracite and bituminous mines abound. In the canalized portions of the Ohio, Allegheny and Monongahela Rivers trouble has arisen at times peculiar thereto.

In some sections storage of water has been developed to a high degree, as at Wilkes-Barre and Scranton and in the Pottsville and Johnstown districts. Here trouble is encountered due to growth of microörganisms and control measures naturally assume much importance.

Also, in some of the mining districts the water from drilled wells has a sulphurous odor and presents its own problem of elimination.

Thus the factors are present for the creation of problems of diverse character, in some instances fairly general throughout the State and in others largely localized.

CONTROL MEASURES

Phenolic compounds

One of the worst offenders in the production of offensive tastes and odors in public water supplies is industrial waste containing phenolic substances, and in previous years considerable trouble was encountered in connection with such wastes in Pennsylvania, chiefly from artificial gas works and byproduct coke plants; also, in some instances, from oil refineries. Unquestionably, where possible, the best method of eliminating tastes and odors due to industrial wastes is by preventing such wastes from entering the water supply, and this is the general principle upon which we have based our control measures.

Not many years ago the wastes from a considerable number of artificial gas works frequently, and, in some instances continuously, found their way into the streams. Under unfavorable conditions, such as lack of sufficient diluting water or the passage of the waste in the form of a slug over the intake, bad water resulted as a matter of course. Accordingly, a campaign was undertaken in coöperation with the owners of gas works to bring about the complete cessation of the discharge of such wastes into the streams, resulting in the installation of equipment and control devices, some profitable, in virtually every offending gas plant in the State, so that today, except in case of an accident, we rarely are troubled with bad tasting water from this cause. This condition exists in spite of the fact that only the northern and western portions of Pennsylvania are supplied with natural gas; elsewhere the product is manufactured and many large plants are situated on streams much used for public water supplies.

There is an interesting story connected with control measures at byproduct coke plants. There are eleven such plants in Pennsylvania: two in the Philadelphia district, one on the Schuylkill River and one on the Delaware River, one at Bethlehem on the Lehigh River, another at Steelton on the Susquehanna River, one at Johnstown on the Conemaugh River, and on the Monongahela River there are two plants including the Clairton works, which formerly was the largest byproduct coke works in the world and has since been doubled in

capacity. Below Pittsburgh there are three plants on the Ohio River, with the remaining one on Lake Erie.

As a preventive measure, in July, 1928, the Sanitary Water Board of the Commonwealth of Pennsylvania entered into an agreement with companies in the State operating byproduct coke plants, executed by all except one of the eleven companies. In accordance therewith the byproduct coke industries have installed and are now operating equipment and apparatus for the elimination of untreated waste waters produced in byproduct coke plants capable of causing offensive tastes and odors in public water supplies, to prevent harm to such supplies. These companies have agreed to maintain such devices and equipment in an adequate state of efficiency, to sample and test the effluents from the various plant equipment and apparatus at sufficiently frequent intervals to detect the presence of such offensive materials as may occur through accident, corrosion of apparatus or other causes; to promptly notify the Sanitary Water Board of any accident to the plant equipment which might impair the efficient elimination or treatment of such waste waters and to make expeditious repair of such equipment and likewise promptly adopt emergency remedial measures.

On the other hand, the Sanitary Water Board agrees, inter alia, to give notice to waterworks in Pennsylvania likely to be affected by the effluent from the plant where an accident occurs, in order that the operation of such waterworks may be modified, if practicable, to prevent or minimize offensive tastes in the water supply as delivered to the consumers; and also to give notice to the Health Departments of down-stream states in order that they may likewise notify their waterworks.

This procedure has worked out quite successfully. Accidental spills have occurred occasionally and notice has been promptly given to the Health Department, and the information transmitted by telephone to our own waterworks in Pennsylvania which might be affected, and coincidentally the Health Departments down-stream have been informed of the occurrence. River flow time tables have been worked out by which it is possible to forecast, within reasonable limits, when the offensive water is due to reach a given waterworks intake. If an affected waterworks is able to do so, pumping is deferred until the bad water passes; otherwise, control measures such as the introduction of ammonia-chlorine into the water supply, are instituted, with the result that either no effect is noticed, or the effect

is reduced to a minimum. This method of control is practicable, but it must be based upon complete and wholehearted coöperation between all concerned.

In spite of such precaution, sometimes accidents happen which cannot be foreseen and this emphasizes the need for the water plants to have at hand means of handling these troubles, such as now are available. A year or two ago in late winter, some of the filtration plants on the Allegheny River above Pittsburgh, were suddenly troubled with offensive tastes and odors in their supplies, and a careful investigation by Health Department engineers did not immediately disclose the cause, except to indicate that there was no trouble of this character in the Allegheny above the mouth of the Kiskiminetas River, on which stream, in the upper reaches, there is a large byproduct coke works at Johnstown. However, this had been investigated and was eliminated as a cause. No content with the negative result of the investigation, it was continued, and it was finally ascertained that the trouble had been caused as the result of a railroad freight wreck along the Kiskminetas River, in which a tank car of road oil had been wrecked and the contents spilled into the cinder fill of the road bed. This happened in mid-winter when the ground was frozen, and no trouble followed until later in the winter after a heavy rain and thaw when the road oil was washed into the stream, and sufficiently long thereafter to cover its travel down to the Allegheny, complaining consumers began to make trouble for the waterworks operators along that stream.

Ammonia-chlorine has usually been found effective in handling a water containing phenolic wastes, although not in every case. At McKeesport, securing its supply from the Monongahela River, a stream receiving sewage and industrial wastes, infrequently phenolic, the ammonia-chlorine process is in use, and since its adoption a general improvement has been noticed in the taste of the treated water. Prior to its use small amounts of residual chlorine produced chlorinous tastes. Upon one occasion, however, a combined chlorinous taste was produced even with the ammonia-chlorine process in use.

Farther down stream the South Pittsburgh Water Company has experienced much trouble in handling the Monongahela water and has experimented with various control methods. Both ammonia-chlorine and activated carbon (Nuchar No. 2) have been used, and we understand that activated carbon appears to have been more successful than ammonia-chlorine and it is used regularly when tastes

and odors are present in raw water. At the beginning the carbon was applied to the raw water at the rate of 1.0 grain per gallon, this dose later being reduced to 0.5 grain per gallon. Subsequently the point of application of carbon was changed from the raw water to the applied water and the dosage reduced to 0.1 grain per gallon. It should be borne in mind in connection with this supply, that ordinarily it is not likely to be troubled with phenolic wastes, but the river at times has musty tastes which have been successfully eliminated by the application of activated carbon, and in some instances the carbon has eliminated phenolic tastes and odors from this supply.

Goehring (1) has interestingly reported upon his experiences on the Beaver River, a stream considerably subjected to taste and odor troubles both by industrial wastes and from natural river causes. In Pennsylvania and also in Ohio on the watershed of the Beaver, there are industries such as byproduct coke plants, steel mills and allied concerns, whose wastes, under certain conditions, produce much trouble for these Beaver Valley plants. For the details of his battle against chlor-phenolic tastes, I recommend that you read Mr. Goehring's paper, it is an interesting one, and will content myself merely to quote one of his conclusions:

> "The ammonia-chlorine process has proven itself valuable in minimizing chlor-phenolic tastes and odors. It will not remove phenols, but prevents their intensification upon chlorination."

Enough, perhaps, has been said to indicate that troubles of this character confront a number of Pennsylvania waterworks and must be reckoned with. One phase of the difficulty is that frequently the problem is not clear cut, such as would arise from the presence alone of phenolic compounds, but on these large rivers receiving many forms of pollution, such as sewage, mine drainage and various industrial wastes, complex mixtures, not always understood, occur and the difficulty of successfully handling water of this character is greatly increased. Sometimes one thing is successful and again fails of success. A good example is the Chester case which will be referred to later.

Microörganisms

Surface supplies predominate in Pennsylvania water works. In general, supplies for the larger cities and towns are taken from the principal rivers and have troubles peculiar thereto, yet there are a

great many supplies secured from smaller streams where impounding is resorted to, and among some of these, as might be expected, we find tastes and odors produced by the micro-organisms which are prone to infest supplies of this character. The usual control measures are generally applied throughout the State. Copper sulphate is a favorite chemical, although chlorine has been used with success in some instances. As elsewhere, infestations have taken place without the knowledge of the operators, when perhaps more vigilance might have forestalled some of the resultant trouble. It seems rather strange that waterworks operators who know, with reasonable certainty, that their supply is likely to be infested with an algae growth each year, wait until it actually happens before taking any steps to control it. Within reasonable limits trouble of this sort is susceptible to control or at least it can be minimized, and to illustrate this point I have drawn freely from data supplied the writer by George R. Taylor of Scranton, Sanitary Chemist of the Scranton-Spring Brook Water Service Company, who has had many years' experience in handling successfully problems of this sort in connection with the supplies of the Scranton-Wilkes-Barre district.

To appreciate the nature of Mr. Taylor's problems here, it should be remembered that this water district extends from Plymouth on the Susquehanna River to the mouth of the Lackawanna River and thence up that valley to Forest City, a total distance of 45 miles; a densely settled territory having an aggregate population of 600,000. The streams in the valley, except for the Susquehanna River, are for the most part rendered useless for water supply purposes because of mine drainage, and, consequently, resort has been had to the upland streams where storage has been developed to a marked degree, resulting in the creation of enormous impounding reservoirs, setting up a favorable environment for the development of micro-organisms. One characteristic of this water development is the building of many and not merely a few storage reservoirs, each of which may have its own peculiarity. In only three instances is the water supply filtered, chlorination otherwise being depended upon.

Mr. Taylor entitles his contribution "Copper Sulphate and Algae," and although this is worthy of publication in full, space will permit only abstracts:

"The first attitude toward algae is prevention. We should make regular microscopic examinations to know what algae are in the water. This should be once a week at least. The samples should be taken from the reservoirs, not

from the taps. Some of the more fragile organisms such as Uroglena entirely disappear between the source of supply and the taps.

"Copper sulphate is best applied before the growth gets to its maximum. Just when to apply it on the basis of algae count will depend on the organisms. It may be 2–300 with many of the diatoms; less with blue greens; while with Uroglena or Synura, I apply it when the count reaches two or three per c.c.

"I find that 4 pounds per m.g. will give a reservoir a thorough cleaning that will last most of the season, if conditions are not too bad. You may not get the whole reduction the first week, but by the end of two weeks the diatoms—and these are the hardest to kill—will have almost completely disappeared. Algae counts will drop to less than 50.

"In the blue green and green group 2 pounds per m.g. will kill very effectively. Most of the common protozoa are likwise killed by this dose.

"Our most common organisms are Asterionella, Anabaena, Cylindrospermum, Synura, Uroglena and Dinobryon. Anabaena and Cylindrospermum are warm water growths. The others will grow at any temperature. Here is a warning on Uroglena: Sometimes even one or two per cc. will cause taste in scattered portions of the system. It is very fragile and may break up even in the bottle between the reservoir and the laboratory. The taste is very intense and peculiar to the organism. . . .

"I have not had what you could call failures with copper sulphate on our storage reservoirs. There have been cases where we have used too small a dose, and in a month or so have had to repeat. As I say, I have gradually come to the opinion that a heavy dose is the most effective in all ways. Certainly a heavy dose is far more lasting than two light doses.

"There seems to be a tendency for types to die out with repeated doses of copper sulphate. Anabaena is not nearly as common in our reservoirs as it was when I began treatment in 1908. More resistant organisms, such as the diatoms, do not show this tendency.

"I have twice treated one of our reservoirs through the ice for Uroglena. Once was a complete success—the second time was not. The method was the usual one of cutting holes through the ice every fifty feet and pumping in copper sulphate solution.

"Fish killing, when we began treatment in 1908, was very prevalent. The first time we treated Lake Scranton we killed fish by the thousands. The tendency has been to kill less fish either because they have become accustomed to the copper or because they have decreased in actual numbers in the reservoirs.

"My experience points to this under Scranton conditions:

Regular microscopic examination
Prevention treatment, if you are quick enough
Heavy doses for most organisms"

Just a word as to fish killing. Almost every water-works man who has been troubled with algae must likewise be confronted with the necessity of controlling it without undue fish killing, and has had to adapt his treatment so as to reduce this to a minimum. Recognizing the problem confronting public waterworks, the Sanitary Water

Board of Pennsylvania, of which the Commissioner of Fisheries is a member, on September 5, 1923, adopted the following resolution:

"Whereas, At times the presence of algae in sources of water supply is the cause of offensive tastes and odors in the water as used by the consumers, which constitutes an indirect menace to the public health, ...

"Whereas, The usual remedial measures for these conditions are the reasonable use of copper sulphate as an algaecide,. . . .

"*Resolved*, That the reasonable use, under the direction or with the sanction of the Department of Health of copper sulphate as an algaecide in reservoirs, lakes or ponds used as sources of public water supply . . . . shall not be deemed a violation of the Fish Law of 1917."

One or two other examples may be of interest on the subject of algae control:

Greenville has a rapid sand filter plant, upland source of supply, and a large concrete clearwell and distributing reservoir having a capacity of about a week's supply. The plant has experienced trouble from algae growths in the clearwell or distribution reservoir for years and they have used large amounts of copper sulphate during warm weather without entirely satisfactory results. The use of ammonia in conjunction with chlorine has permitted carrying a high residual without the usual accompanying chlorinous taste. The reservoir has been free of algae growths during the past two years and after-growths have not been experienced as before following copper sulphate treatments.

At Elizabeth, on the Monongahela River, during the 1930 drought a noticeable fishy odor appeared, believed to have been due to microscopic organisms. Activated carbon (Nuchar No. 2) was applied to the raw water and successfully eliminated the fishy odor in the treated water supply.

A public supply in Eastern Pennsylvania taken from an abandoned limestone quarry, with a capacity estimated at 40 million gallons, was put into use during 1930, and is chlorinated and softened in zeolite filters. Just about the time the installation was completed the water in the quarry became infested with algae and tastes and odors appeared throughout the distribution system. In order to overcome these tastes and odors heavy applications of copper sulphate were made to the raw water which resulted in the reduction of the numbers of organisms, but did not remove the tastes and odors.

The entire body of water was then treated with alum, applied from a boat with an outboard motor, and later with activated carbon

applied in the same manner. After several applications of this latter chemical the tastes and odors disappeared.

"River" tastes

The drought of 1930–1931 brought many problems to public waterworks, and one that was quite vexatious was the handling of the so-called "river taste" described as musty, moldy, woody, and particularly noticeable on the western rivers which have been canalized by the construction of navigation dams. Mention has already been made of the South Pittsburgh Water Company's experience, which at times experiences woody river tastes and where activated carbon proved successful. Several plants on the Allegheny River near Pittsburgh, experienced a very noticeable taste and odor in their raw water in the fall of 1930. At the Natrona plant experiments were made with activated carbon, but since at the beginning there were no facilities to introduce the carbon into the raw water supply ahead of sedimentation, activated carbon was applied at the rate of one grain per gallon to the water leaving the sedimentation basins and going onto the filters. At that time an excessive amount of floc was being carried over onto the filters and the contact period for the carbon was very short. Effective results were not secured. Then the point of application was changed to the water entering the sedimentation basin and a dosage of two grains per gallon applied. The floc in the basin was excessive and although sufficient contact period was afforded, effective results were not obtained. Jar tests were made with carbon on filtered water, and the musty taste and odor were removed. It was thought in this experiment that the excessive floc enmeshed the activated carbon and destroyed its effectiveness.

Three other Allegheny River plants in the same general vicinity had similar taste and odor troubles and used ammonia-chlorine, but this process as it was normally used did not eliminate the tastes and odors, but a reduction in their intensity was believed to be effected by this process. The dosage of ammonia was varied without completely eliminating tastes and odors. In addition to the ammonia-chlorine process at the Tarentum plant, pre-chlorination of the raw water was resorted to followed by ammonia-chlorine treatment, but satisfactory results were not obtained.

At New Castle on the Shenango River, there is a wide variation in the character of the raw water supply, and the trouble encountered here with unusual tastes and odors and the methods used to combat

them, are well described by Johnson (2), Chemist, City of New Castle Water Company. His conclusions show the successful use of activated carbon at his plant:

"1. Abnormal tastes and odors in the New Castle water supply have been most completely removed by the use of activated carbon.

"2. When properly applied activated carbon treatment has not interfered with filter plant operations and has been economical in cost.

"3. With the exception of a mild but bitter straw-like taste activated carbon has removed all objectionable tastes that have appeared in the supply since its use was begun.

"4. Activated carbon treatment appeals to the public mind because of its simplicity. After absorption of the substances causing tastes the carbon itself is removed also; whereas, all or parts of other chemical agents used remain in the water and may possibly contribute some tastes or have unknown and undesirable physiological effects.

"5. The use of activated carbon has been controlled by the concentrate tests. These have indicated both the kind and quantity of treatment to be used if any was needed. The test is as important in the control of taste and odor as is the alkalinity or pH in the control of coagulation."

Allied with the river problems are those arising in storage reservoirs where bad tasting water occurs due to stagnant conditions. This has usually been found in the deeper reservoirs, and the writer is not offering it as a new phenomenon, but merely to direct attention to it as having a place in the discussion of tastes and odors. The Department's District Engineer in the Scranton-Wilkes-Barre section reports that the water from the large impounding reservoirs at times has a peculiar odor, but that this is corrected by drawing off the water from a higher level. This is quite a common happening and the above remedy is usually effective.

In another part of the State this summer trouble occurred in a large impounding reservoir due to a combination of stagnant water from the bottom of the reservoir and of algae. Changing the outlet to a higher level corrected the stagnant water trouble and copper sulphate killed the algae. In passing, it may be noted that in this particular supply an attempt was made to correct the trouble by using potassium permanganate, but without any marked success.

Martin E. Flentje, Superintendent of Purification, Community Water Service Company, has supplied the writer with several interesting cases falling within his experience on Pennsylvania plants, and those of Apollo and Derry are quoted. The installation of a flexible intake as described by Mr. Flentje may be applicable in other similar cases:

"Tastes and odors at Apollo apparently were most pronounced when Gilkerson Reservoir was used. We found that these tastes were largely due to stagnant conditions as the outlet pipe of this reservoir was right on the bottom in about 20-25 feet of water. The stagnant layer of water extended upward about 5-10 feet from the bottom. This water was decidedly disagreeable in odor, but was made satisfactory with activated carbon in doses up to slightly over ½ grain per gallon, aeration, and treatment with ammonia and chlorine. To remedy this condition we have installed an intake pipe with a 'swinging joint' so that water from any level can be taken. We have not as yet been able to thoroughly try this out. Then we also put in an activated carbon application system so that we can add carbon in several different places. We normally apply it in doses of 6-10 lbs. per m.g. continuously just ahead of the filters. We feel it has helped, although it does not seem to remove all of every kind of taste. We also find that applying ammonia in our clear well just ahead of chlorination allows us to carry considerably higher residuals than we could otherwise.

"At Derry we had similar trouble this summer—stagnant condition in the lower portions of our Ethyl Springs Reservoir. The intake in this reservoir was also on or near the bottom, and the water quite suddenly became turbid and, even after aeration and settling in a basin, contained a bad taste and odor. Increasing the residual chlorine helped some, but the situation was completely fixed up by having a diver put in another 'swinging joint' type of movable intake. While the water is some warmer in temperature it is clear and free of taste and odor. . . . . "

"These cover our Pennsylvania experiences lately. My general reaction is that after tastes and odors due to careless regulation or residual chlorine are eliminated, a large proportion of the troubles remaining are from water from the stagnant areas of reservoirs. Practically no old reservoirs have anything more than just one intake and that at the bottom, the worst possible place. Aeration helps this taste some, chlorinating more heavily helps I believe, but carbon seems to remove quite well, if no large amount of H_2S is present. . . . ."

Chester, with an unusually difficult water to handle, affords a good example of success secured only after elaborate experimentation, with trial of various control methods, some effective elsewhere. This is the only plant in Pennsylvania using absorbing clay as a taste and odor remover.

The Delaware River is the source of water supply, the watershed containing highly developed industrial territory with plants of many types. Norcom and Dodd (3) in 1930 described the experiments with activated carbon, and this summer Slocum (4) and Dodd (5) related the use of absorbing clay.

Dodd says:

"Taste and odor producing substances in the Delaware at Chester are numerous, but the most offensive and the most difficult to remove are those as-

sociated or derived from oils, probably the end products from gasoline and oil distillations.

"Due to the potency of minute quantities of these substances in producing tastes and odors they have been most difficult to remove.

"So little is known about the nature and possible combination of the offending substances, that it has been like dealing with the intangible."

Begun first as an experiment, it is now in daily use. The clay is introduced at the intake. Thereafter the water is pre-chlorinated, twice aerated, coagulated, settled, filtered, post-chlorinated and limed, when necessary. Ammonia-chlorine was used in 1931 and is available if needed.

Dodd further remarks:

"The determining factor as to the quantity of clay used is the condition of the raw water. So far the dosage has ranged from 0.1 to 0.6 grain per gallon, with an average of 0.3 g.p.g., making an average cost of $0.35 per million gallons.

"It is our opinion that the clay absorbs most of the highly hydrolized oily substances, phenols, etc. The aeration removes the more volatile oils and drives off gases. Prechlorination oxidizes the organic matter, and kills taste and odor producing organisms. Coagulation, settling and filtration in this case become finishing operations."

Aeration

Aeration devices are found in almost every part of Pennsylvania. Some have been installed solely for the removal of odors, while others serve a dual purpose; odor removal and CO_2 reduction; as well as iron removal in some cases. For this latter purpose they have not proven very effective. For the release of H_2S they have quite generally been reasonably successful, in some instances failing in complete removal. At Chester aeration combined with prechlorination is thought to aid materially in the control of taste and odors. At Clarion the water from the wells is high in H_2S and CO_2. Sprayco nozzles are effective for H_2S removal and the CO_2 is reduced from 70 to 6.6 p.p.m.

The aerators range from the simple vertical pipe, with the water overflowing into the basin, to rather elaborate devices with nozzles, tray or jet action. In the drilled well supplies the air lift probably helps. At one small drilled well supply water is discharged into the air from the vertical casing and an electric fan blows air through the falling film of water. Some removal of H_2S is noted. This was adopted because of limited space.

Prechlorination

Several plants have prechlorination, installed primarily to improve bacterial reduction. Incidentally, it has been found of value in taste and odor control. In the Philadelphia District this experience was noted on several large plants, but here, as elsewhere, the improvement in palatability was secondary to the real purpose of the installation, that of bacterial control.

At Waynesboro, with an upland supply, trouble was encountered in bacterial reduction and maintenance of suitable chlorine residuals on the distribution system. Ammonia-chlorine treatment reduced the bacteria satisfactorily and incidentally eliminated a slight musty taste and odor annoyingly persistent in the tap water.

Slow sand vs. rapid sand filters

Lyle L. Jenne (6), Sanitary Engineer, Bureau of Water, Philadelphia, reporting his experience with these two types of filters, using the same water, states that the slow sand filters have always produced more palatable water than the rapid sand filters. This was on Schuylkill River water troubled with ordinary "river tastes" and also those due to industrial wastes, or combinations of these. A similar experience has been noted on the Allegheny River.

Installations in Pennsylvania

Pennsylvania waterworks have not been slow to adopt modern methods of taste and odor control. At the end of 1931 some 65 public waterworks used regularly or occasionally one or more control methods. Thus 21 employ activated carbon, 32 ammonia-chlorine, 11 have prechlorination and one uses absorbing clay.

CONCLUSIONS

From our experiences in Pennsylvania, we draw several conclusions generally applicable where control methods are used:

1. No one method can be considered as the panacea or "cure-all" for all the evils of bad tasting and bad smelling water. Each has its value when properly applied.

2. The point of application is important; often only by trial can the best place be ascertained.

3. It should not be concluded that because a given method fails of success, some other one will not work out satisfactorily. Consequently, a trial of different methods or combination of methods and

different points of application might well be undertaken before the conclusion is reached that nothing can be done to control the trouble.

4. For algae control, the operator must be eternally vigilant. When trouble occurs, prompt action must be taken. Routine procedure for the detection of algae and its control should be established. Heavy doses of copper sulphate, where practicable, are more efficient than lighter doses.

5. In reservoirs with multi-level outlets, close observation should be kept on the water so as to draw it from the best level. In existing reservoirs, where trouble occurs from stagnant water, it might be well to consider the installation of multi-level outlets or an adjustable outlet. This will apply as well in the design of new reservoirs.

In closing I desire to express my appreciation of the helpful cooperation of my colleagues in the Bureau of Engineering, who supplied much of the data used in this paper.

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(*Presented before the Central States Section meeting, September 23, 1932.*)

THE HISTORY OF WASHINGTON'S WATER SUPPLY SYSTEM

By J. D. Arthur, Jr.

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While a history of Washington's Water Supply System properly begins in 1819, when the supply of a spring in Franklin Square was piped to the Executive offices and the White House, the existing system had its inception in a project submitted to Congress in 1853 by the Corps of Engineers, U. S. Army. This project, prepared by then Lieutenant, later General Meigs, consisted of a dam across the Potomac River at Great Falls; a circular brick gravity conduit 9 feet in diameter and about 11 miles long; a receiving reservoir at Dalecarlia; the Georgetown distribution reservoir; and a high service reservoir at R Street and Wisconsin Avenue to serve that part of the city too high to be supplied by gravity.

Work commenced in November, 1853, but annual appropriations were small and water from the Potomac did not enter the system until 1863. As might be expected, its quality, judged by modern standards, left much to desire. Some turbidity was removed in the reservoirs, but there are reports that an occasional eel found its way to the frying pan by way of the water faucets in city kitchens.

Two interesting bridges were elements of this early system. One, the Cabin John Arch which carries the conduit over Cabin John Creek, is a single span masonry arch 220 feet long and was for some 40 years the largest masonry arch in the world and is still the largest in this country. The Rock Creek Bridge on Pennsylvania Avenue is unusual in that two 48-inch cast iron water mains were constructed in the form of a 200 feet span arch, on which the roadway is supported.

Not until 1882 were any improvements in the early system undertaken. In that year Congress authorized the raising of the dam at Great Falls; the extension of the aqueduct by tunnel from Georgetown Reservoir to the site selected for a new reservoir in McMillan Park; and the construction of this new reservoir. The tunnel from Georgetown to McMillan is about 4 miles long entirely through rock,

and is between 100 and 150 feet below the level of the city streets. Even after the completion of this project, however, the citizens of Washington were supplied with water improved only by sedimentation. Not until 1905, when the McMillan Filtration Plant and the Bryant Street Pumping Station were completed, was the city supplied with filtered water.

The filtration plant is of the slow sand type. From McMillan Reservoir, three steam driven low service pumps deliver water to the 29 filter beds, each with an effective sand area of one acre, and a total capacity of 80,000,000 gallons per day. At the time of its construction, practically the entire city could be supplied from this plant by gravity flow, but to serve the higher sections of the city the Bryant Street Pumping Station was constructed. At the present time, it serves as a standby plant for the Dalecarlia Station and augments its capacity during periods of maximum consumption.

With the great growth in population in Washington during the following years, further expansion of the system became necessary, and in 1921 work was commenced on a new project. This called for a new concrete conduit laid practically parallel to the old; a rapid sand filtration plant at Dalecarlia; a hydroelectric plant; an electrical pumping station; two new storage reservoirs; and necessary connecting mains. This program was completed in 1928.

I have outlined the various steps by which the existing system has been developed, and perhaps its present functioning can be best understood by the description which follows.

From Great Falls, the two conduits, with a combined capacity of 185,000,000 gallons per day, deliver the water of the Potomac River to Dalecarlia Reservoir. Incidentally, this capacity is in process of being increased to 217,000,000 by a lowering of the water elevation at the outlet, and the creation of a two-level lake in the reservoir by the construction of a dam and booster pumping station.

From Dalecarlia Reservoir, the water is distributed three ways. One portion goes to the filters at Dalecarlia, from which after filtration it is pumped to 3 distributing reservoirs, known as the 1st, 2nd, and 3rd High, and thence flows by gravity to the consumers of the city. Another portion goes to Georgetown Reservoir, thence by tunnel to McMillan Reservoir, where it is pumped to the filters, and then flows by gravity to the consumers. All water not needed to meet local consumption flows through a 72-inch penstock to the hydro plant on the river bank, where the energy is converted into electricity to operate the pumping station.

The operation of this system is somewhat unusual. Prior to 1882, it was entirely under Federal control. But in that year, Congress created a Water Department in the District of Columbia government, and charged it with responsibility for distribution to the ultimate consumers. All phases of collection and purification remained under Federal control, however, and at the present time the United States, through the Corps of Engineers, U. S. Army, delivers filtered water to the various distributing reservoirs, and there its activities cease. All phases of distribution, including distributing mains, fire-hydrants, metering, etc., are handled by the Water Department of the city.

(Presented before the 4-States Section meeting, April 27, 1933.)

OPERATION OF WATER FILTRATION PLANTS

INTRODUCTION

By N. J. Howard

(Director of Water Purification, Toronto, Ont., Can.)

In opening the symposium on the operation of water purification plants, it is proposed to touch very briefly upon the essential features involved. Those who follow, will doubtless give details of the problems actually encountered and describe what steps were employed in their solution.

It is assumed that, before a water treatment plant is built, technical advice is sought in order to determine the most suitable source of supply and to ascertain the most effective and economical type of treatment. It is further assumed that where more than one source is available, the water having the greatest organic purity will be given preference, provided, of course, that the capital expenditure involved is reasonable and that the physical and hardness conditions of the water are not objectionable. With these points in mind consideration should be given to the reaction of the water, the possibility of coagulating difficulties and the palatability of the finished product.

In only selecting difficult types of water to discuss, it is felt that common practice upon ordinary supplies is so well established that it does not need recapitulation here. Experimental plants or research laboratory work can alone demonstrate the necessary treatment for soft or hard, colored supplies. Without such work being undertaken, frequent troubles arise when the treatment plant has been completed. Such troubles include coagulating difficulties which result in the occasional production of red water, secondary precipitation in remote parts of the distribution system and the periodic passage of colored water. Before filtration, it is essential to determine the most suitable chemical reagent for both of these types of water, in order to secure the greatest color and hardness removal at the smallest cost. Much work is often necessary to determine the most effective and economical chemical or coagulant to use. A good deal of money can be wasted by the use of unsuitable reagents or by overdosing

with coagulants. It is not always necessary to have a large visible floc formation to secure satisfactory filtration results, although, generally speaking, the best results are obtained when a good, stabilised floc has been formed. The question of adequate mixing and sedimentation of the pre-filtration water, has much to do with successful treatment, the removal of color and length of filter runs being greatly influenced by these factors. Special attention should be given to the filter sand to determine the most effective size for the supply under consideration. It seems probable that in the near future, the question of the size of sand will become a major issue, involving coarser sand and increased rates of filtration. The prevention of mud ball formation and surface shrinkage of sand beds, is closely related to the size of sand and effective backwashing of the filters. In designing the backwashing system, if greater consideration was given to the maximum and minimum water temperatures which play such a large part in satisfactory washing, it is possible that less filter trouble would be experienced. Work carried out by L. F. Allan at the Toronto Filtration Plant during the past year, using experimental units, has brought out surprising results in sand expansion studies, and may prove of considerable value in operating the new plant at Victoria Park.

The hardness of water is receiving increasing attention. In fact, it is frequently claimed that municipalities are not now justified in delivering excessively hard water to their consumers. In Canada we seem at last to be realising the enormous economic value of a softened supply. The process of softening is always a local problem, involving a study of the chemistry of the water and the most suitable and economical process to be employed. The preliminary cost is often reasonable, but the maintenance costs may be high. Nevertheless the ultimate saving to the consumers in general, will be found to more than offset the capital and operating costs.

Assuming that most of the physical properties aimed at have been achieved, one of the most important objects of a water treatment process, is to deliver to the consumers a finished product which is not only clear, bright and non-corrosive, but also one that is palatable and free from all taste and odor. While this is sometimes difficult notably in old plants, modern practice has made provision to solve almost all kinds of offensive tastes and odors. To meet this problem aeration, pre- and super-chlorination, pre-ammoniation and activated carbon treatment have been developed. Not one of these

methods are cure-alls, yet when employed either separately or jointly all processes have demonstrated their ability to successfully remedy offensive conditions. Before any of these methods are employed, experimental work should be undertaken not only to determine their effectiveness, but also to make sure that the filtration process is not adversely impaired.

In reviewing the subject under discussion as a whole, one would plead for close co-operation between the engineer, chemist and plant operator. If the plant is to be efficiently and economically operated, this is essential. At present water treatment has been so perfected that, except in unusual circumstances, no justification exists for hard, colored or corrosive domestic supplies or for the distribution of an unpalatable water. Progress made during the past twenty-five years in water purification, resulting in the production of water of modern day requirements and in the practical elimination of water borne disease, ranks amongst the greatest achievements of the present century.

THE BRANTFORD PLANT

By F. P. Adams

(*City Engineer, Brantford, Ont., Can.*)

Our filtration plant is a rapid sand gravity plant of 6 m.g.d. (U. S.) capacity.

The water is raised from the suction well to the coagulation basins through a mixing chamber at one end of the basins. The coagulation basins have a retention period of two hours when the plant is running to capacity. There are six filters of 1 m.g.d. capacity each. Wash water is supplied from an elevated tank and the filters are designed for a rise of 30 inches per minute during the backwash. There is a filtered water storage reservoir of 1,000,000 Imperial gallons.

The supply is taken from the Grand River which is subject to extreme variations of flow. During the spring freshets the water is heavily charged with silt giving as high as 1000 p.p.m. turbidity. The color increasing from 20 to 60 to 80.

The flow of the river during the summer months is as low as 500 c.f.s., while during flood periods it has discharged as high as 50,000 c.f.s. These conditions create sudden changes in the quality of the raw water to be treated.

Before the present plant was built the supply for the city was

obtained from a gravel deposit adjacent to the river. The river was conducted into the gravel through tile conduits perforated throughout their length, and collected through similar parallel conduits after undergoing natural filtration through the gravel. This supply is still available, although not in quantity sufficient to furnish the full requirements of the city. While floods are at their worst this water is mixed with the raw river water to supply the filters, and thus the load on the filters is reduced. A uniformly bright, clear water is obtained throughout the year with a minimum cost for chemicals.

Our present demand varies from 2½ to 3 million Imperial gallons per day. With this demand we can, by regulating the ground water and river water proportions, supply the filters with raw water having a color of from 20 to 30 under all conditions of the river.

Preliminary tests on the raw water indicated that from 2 to 3 grains per Imperial gallon of alum would be required to properly coagulate it, and when the plant was first put into operation a 3 grain dose was used. This was later reduced to 2 grains and a fair floc was obtained. Later on prechlorination was introduced and the alum dose was gradually reduced until at present only 0.5 g.p.g. is used. The dose of chlorine to the raw water is at present 4½ pounds per million gallons. This does not show any color with the ortho-tolidin test in the filtered water. Just before the water is pumped to the city a further dose of 2½ pounds per million gallons is added and this gives a free chlorine residual of 0.1 plus to the finished water.

Under this treatment the water supplied the city has a color of 10 or less. It is sparkling and we have had no complaints of chlorine tastes.

Samples taken from the coagulation basins, filters, clear water well, and city tap by the Department of Health, Toronto, have invariably shown Class A water from a bacterial standpoint, while the river water, and water from the raw water suction well are usually Class D.

When the heavy doses of alum were being used before pre-chlorination it looked as if we were in for trouble with the sand on the filters. Small balls of sand were forming about the size of peas and the chemical was crystallizing out on the filter walls. This trouble has now entirely disappeared.

Our filter runs are 48 hours between washings and the wash water used is 3⅓ per cent of the water filtered.

The uniform operating conditions and uniform results are due

to the steadying influence of the ground water supply available for mixing with the variable river supply. As the city demand increases this advantage will tend to diminish.

Where turbidity and color are subject to extreme and sudden changes it is desirable that designing engineers consider the inclusion of impounding supplies under normal conditions of flow for use during extreme conditions. A moderately uniform raw water means large savings on chemicals, to say nothing of the more uniform product furnished to the public.

THE OTTAWA PLANT

By H. P. Stockwell

(*Chemist, Filtration Plant, Ottawa, Ont., Can.*)

The Water Purification Plant at Ottawa was officially opened on April 30, 1932, after having been operated on a semi-experimental basis for over two weeks. This preliminary operation of the plant was carried on in order to adjust all control apparatus to operating conditions and to train the staff in the operation of the plant by manual control before the automatic features had commenced to function. Coming as it did at the time of the Spring run-off, the change from the raw Ottawa River water to the filtered supply presented a contrast that was particularly striking. Within twenty-four hours the water supplied throughout the city had changed from a highly colored, turbid and unpleasant tasting liquid to a clear, sparkling and palatable product.

This plant is furnished with the soft, but rather highly colored water of the Ottawa River and the main problem is that of color removal. The raw water has the following characteristics: pH from 6.9 to 7.4; color 40 to 80; turbidity 8 to 100, this is usually low except during the Spring run-off; alkalinity 16 to 38 and total hardness 35 to 70.

Preliminary to the design and construction of the water purification plant, an exhaustive study of the chemical treatment of this water was carried out by George G. Nasmith, of Gore, Nasmith and Storrie, Consulting Engineers, Toronto, Ont., in the 96,000 Imperial gallon trial filtration plant constructed and operated under their supervision. As a result of tests carried out with various coagulants and over a period long enough to include all seasonal variations in raw water

conditions, aluminium sulphate was chosen as the most effective coagulating agent.

The most serious problem encountered during this experimental work was that presented by the extreme fragility of the floc. The mixing of the coagulant with the water by means of mechanical agitators was found to be too severe and it was not until, acting on the suggestion of Mr. William Gore, this method had been replaced by a slow continuous spiral movement of the water containing the coagulant, up and down through a series of four deep mixing tanks that a well formed floc and consequent good settling were obtained. This one simplification of the process which was incorporated into the design of the water purification plant has resulted in savings in construction and operating costs which would more than justify the erection of the Trial Filtration Plant had it cost many times the $10,000 expended on it.

A careful study of the action of aluminium sulphate on the Ottawa River water was carried out by Dr. Nasmith who found that the minimum dosage of alum required to give complete color removal was $1\frac{3}{4}$ grains per gallon and this only when the pH of the raw water had been previously adjusted with sulphuric acid so that the pH after addition of alum fell within the range 5.3 to 5.5. When larger dosages of alum are used less acid adjustment is required and color removal is effected over a larger and somewhat higher pH range. As this adjustment of the water with acid can not be considered in plant operation this has to be accomplished by the use of excess alum and thus any change in the pH and alkalinity of the raw water will influence both the alum dosage and the optimum pH for color removal.

This optimum alum dosage is determined by bench experiments whenever changes in the raw water occur. A series of samples of raw water containing varying amounts of alum are placed in jars and stirred slowly for 25 minutes on a Baylis stirring machine; the character of the floc formation is noted and after settling, the supernatant liquid is passed through filter paper and a color determination is made. A typical set of tests on January 14, 1933, is shown in table 1.

This shows the optimum dosage to be $2\frac{5}{8}$ grains per gallon, corresponding to a pH of 5.7 for this raw water. During April, 1932, the pH of the raw water reached 7.3 and the plant was operated successfully with an alum dosage of 3 g.p.g. and a resultant pH of 6.2, while in June the pH of the raw water reached a minimum of 6.9

and the alkalinity 16. Jar tests made at that time showed the best dosage to be $2\frac{3}{8}$ grains per gallon (Imperial) with a corresponding pH of 5.5. Thus the optimum pH for color removal shifts upwards when increased alum treatment is demanded by rise in pH and alkalinity of the raw water. By keeping a close check on the alum treatment in this manner the plant has been operated using a minimum of alum consistent with good color removal. The filter effluent is maintained at an average color of about 3, while the residual alkalinity varies from 3 to 5 p.p.m., as $CaCO_3$.

Alum is fed by one of two International dry chemical feeders with variable feed controlled by the pressure differential at the plant

TABLE 1

Tests for color removal

Raw water: pH 7.1; alkalinity, 22; color, 65

ALUM USED	pH	Color	FLOC FORMATION
g.p.g.			
$1\frac{7}{8}$	6.1	20	None
2	6.1	15	Poor
$2\frac{1}{8}$	6.0	9	Fair
$2\frac{1}{4}$	5.9	8	Fairly good
$2\frac{3}{8}$	5.9	6	Good
$2\frac{1}{2}$	5.9	6	Good
$2\frac{5}{8}$	5.7	2	Good
$2\frac{3}{4}$	5.6	3	Very good
$2\frac{7}{8}$	5.6	3	Very good

influent venturi meter. The chemical room operator records the weight of alum fed and the amount of water pumped to the filter plant for every 15-minute period and makes such small adjustments to the feeding mechanism as are necessary to maintain a constant dosage. These feeders are giving very satisfactory results and with this close supervision there is little if any difference between the required dosage and the actual dosage as calculated from the daily pumpage figures and the weight of alum used. The alum falls from the feeder into a lead tank where it is dissolved in water to form an approximately 5 percent solution. Up to this date this solution has been conducted by gravity flow into the suction well of the low lift pumps. These pumps impart a preliminary rapid mixing before the water reaches the mixing tanks.

The low lift pumps are always full of water, being kept primed when not operating. A deposit of impure hydrated alumina similar to the sludge obtained in the settling basins forms on the inside of the casings. This would not appear to be particularly corrosive, but has an adverse effect on the efficiency of the pump. The question has arisen as to whether a similar deposit might be forming in the venturi tube between these pumps and the mixing tanks, thus interfering with the accuracy of the meter. Because of this possibility the alum solution may in future be injected into the raw water after it has passed the venturi tube. This however, will eliminate the preliminary mixing in the low lift pumps and the alum may not then be sufficiently mixed with the water to insure an equal distribution of the chemical among the three settling basins.

The water containing the required amount of alum passes to the mixing tanks where good floc formation is effected by the slow spiral movement of the water up and down through a set of four deep tanks. This requires about 40 minutes after which the water passes to distributing weirs where the spiral motion is checked and the water enters the settling basins. Here the floc is allowed to settle for a period of from 4 to 8 hours depending upon the rate of filtration. After this, the settled water flows over submerged weirs 18 inches below the surface and is carried by conduits to the rapid sand filters.

The combined efficiency of the chemical treatment and the settling process is determined daily by the procedure worked out by Dr. Nasmith. Samples of water from the mixing tanks and from the settled water conduits are acidified with a few drops of concentrated sulphuric acid to redissolve the floc. The acidified sample from the mixing tanks is then diluted with distilled water until the color matches that of the acidified settled water, the degree of dilution necessary indicating the approximate efficiency of this part of the process. This figure varies between 70 to 75 percent under winter conditions and 80 to 85 percent during the summer months.

Each settling basin is emptied and cleaned free of sludge once every six weeks. This is usually carried out on Sunday evenings when the load is low and the velocity of the water through the other basins will not become too rapid; a greater proportion of the low lift pumping capacity is also available at that time for refilling the basin after cleaning.

The usual procedure is first to close the influent valve to the mixing tanks and the effluent gate from the settling basin to the settled

water conduit. The drainage sluice gate is then opened and the settling basin is emptied, holding back the water in the mixing tanks until nothing remains in the basin except a thick suspension of sludge. The water in the mixing tanks under an initial head of about 20 or 25 feet is then admitted to the basin through the gate in the bottom of the dividing wall; this stirs up the sludge very effectively so that when finally empty the basin contains very little solid material to be washed out with the fire hose. By this method the 2,000,000 gallon basin can be emptied and cleaned in approximately two hours, requiring about four hours to refill. In warm weather there is some putrefaction of the organic matter in the sludge. This contributes probably in some measure to the slight tastes found in the water during the late summer months. It is planned to clean these settling basins more frequently during the coming summer, as well as to add activated carbon to the water in order to eliminate all tastes from the filtered supply.

The floc remaining in the settled water is removed by the ten filter units, each of which is designed to treat $3\frac{1}{2}$ million Imperial gallons per day at the standard rate of 105 million gallons per acre per day. These filters contain 34 inches of Cape Cod sand of 0.47 effective size and 1.39 uniformity coefficient, placed on 20 inches of graded gravel, $\frac{1}{16}$ to $1\frac{1}{2}$ inches in size.

The length of the filter runs is determined by the color of the filter effluent, the loss of head being small. Only on two or three occasions have filters had to be washed because of loss of head and in those cases the low rate of filtration was due to air in the filter bed. One filter is used as a control to set the length of filter runs by determining the time for the effluent to reach a color of 5. On this information is based the operating schedule for the other nine filters. The longest filter runs recorded were during the month of November when runs of as high as 76 hours were obtained, the average for the month being 73 hours. On the other hand, the shortest runs were 48 hours obtained in May.

The filters are not equipped to filter the waste after backwashing as the higher colored effluent obtained for the first half hour of the filter run when mixed with the 6,000,000 gallons of water in the reservoir does not affect the average color of the water leaving the plant to any appreciable extent.

Backwashing is at 30 inches per minute vertical rise for about six minutes or until the turbidity falls to about 75, which requires about

80,000 gallons of water. During the summer season there was some formation of mud balls on the beds, apparently because the 30 inch rate of backwash was not sufficient for the warmer water. These mud balls seem to have been formed by the rolling of floc over the top of the sand, gradually forming a spherical mass of floc and sand sometimes as large as two inches in size. Screen analyses made on the sand obtained by dissolving away the floc in these with caustic soda showed an effective size of 0.31 and uniformity coefficient of 1.23. These figures would indicate that these mud balls are not caused by excessively fine sand as was at first supposed.

As has been previously stated, the pH of the filter effluent varies between 5.5 and 6.2, depending upon the amount of alum treatment necessary. The acidity due to free carbonic acid is corrected by the addition of milk-of-lime to the water passing from the reservoir to the distribution system. During the past summer the pH of the water pumped to the city was 8.4, but during the early winter this was raised to 9.4 or slightly higher because of complaints of rusty water in hot water heaters, although no increase in color or iron content had been noted throughout the distribution system. It has been found difficult to maintain the pH at an exact constant value at all times as very small variations in lime dosage change the pH considerably, but it has been possible to keep this between 9.4 and 9.6 at most times, which is a little above the solubility equilibrium point for calcium carbonate in this water. The color of the filtered water is approximately doubled by the addition of lime, increasing from 2 or 3 to 5 or 6.

Little can be found in the literature regarding the protection of hot water system from corrosive action, although much has been written on red water troubles in general. The maintenance of a protective coating, by lime treatment, in household hot water lines would appear to be difficult because of the increasing solubility of calcium carbonate as the water cools on standing in the pipe, although it should be mentioned that different authorities do not agree as to the temperature solubility relationship of this material. A small amount of colored water can be expected from a pipe where the water has been standing for any time, but this should clear up immediately when the tap is allowed to run. Most complaints have been from homes where the water is heated in iron jacket heaters or in a ring or coil set into the furnace and in all cases violent agitation due to overheating would appear to be the chief cause of this trouble.

The plant is equipped with two Infilco lump lime feeders and slakers with variable feed controlled from the plant effluent venturi tube. These feeders work very well with lump lime ½-inch in size or under, but could not be used for pulverized material. No provision was made in the original installation for the removal of sand or finely divided unburned lime, which is of great importance as the lime is added directly to the water entering the distribution system. Such material soon appeared in the screens protecting the working parts of the hydraulically operated control apparatus, in the water trays of the chlorinators and in other places in the plant where service water was used. It was feared that this could cause damage to the cylinders of the hydraulic valves with which the plant is equipped and would also form undesirable deposits in the pipe lines leaving the plant. Consequently it was thought advisable to screen the milk-of-lime before applying it to the water. The suspension is first passed through a ⅛-inch screen to remove the coarser particles and then through a 60-mesh screen equipped with a suitable shower, to remove the finer impurities. It is felt that anything passing this fine screen would not be sufficiently large to cause damage to any moving parts in the plant.

The lime best suited for the purpose is a quick slaking lime containing a minimum of sand and unburned limestone. This should be in lump form with a maximum size of ½ to ¾ inches and should contain a minimum of fines. One carload was received in pulverized form, practically all passing a 50-mesh screen. This material was extremely difficult to feed correctly with this type of apparatus because of the extreme fineness. Lime of 90 percent available calcium oxide content is being used at the present time with satisfactory results, although during cold weather quicker slaking is obtained if the water to the slaker is heated by steam to a temperature of 60 or 70 degrees, Fahr. The milk-of-lime is kept at a constant temperature of about 120 degrees, by regulating the ratio of water to quick-lime, thus assuring a relatively uniform consistency of the suspension at all times. The screening operation can be the source of much waste of good lime unless the fine screens (60-mesh in this case) are properly fitted with shower pipes on the under side in order to keep the mesh open. The average dosage required to maintain a pH of 9.4 to 9.6 in the plant effluent is about 1.3 grains per gallon.

Disinfection is accomplished by the addition of chlorine to the filtered water, being applied with Wallace and Tiernan chlorinators

controlled from the effluent venturi tube. The dosage required varies from 2½ to 3 pounds per million gallons with which is obtained a residual of 0.05 to 0.10 p.p.m. after 15 minutes contact. Bacteriological control of the water supply is carried out under the direction of Dr. Frank Letts, director of the local laboratory of the Ontario Department of Health, which is supported jointly by that Department and the City of Ottawa. Here daily tests are carried out on samples from taps in various parts of the city as well as on the raw river water, filter effluent and disinfected water from the filtration plant. Although the B. Coli count on the raw water varies from 1

TABLE 2

Typical analyses of Ottawa water

(Results in p.p.m.)

	RAW WATER	FILTER EFFLUENT	PLANT EFFLUENT
pH	7.1	5.7	9.4
Alkalinity (methyl orange)	22	6	34
Alkalinity (phenolphthalein)	0	0	12
Color	60	2	4
Dissolved solids	53.0	48.7	82.8
Soap hardness	33	40	65.5
Iron (Fe)	0.1	0.04	0.04
Manganese (Mn)	0.0	0.0	0.0
Silica (SiO_2)	4.8	4.0	4.5
Calcium (Ca)	11.5	12.0	22.5
Magnesium (Mg)	3.5	3.5	2.0
Sulphate (SO_4)	2.5	21.6	22.8
Chloride (Cl)	2.4	3.8	3.8
Free chlorine			0.075

to 80 in 10 cc. the bacterial efficiency of the coagulation and filtration processes is such that no B. Coli are found in the effluent from the filters, although the presence of plant and soil bacteria is occasionally indicated.

Because of the relatively high dosage of alum used in this plant the chemical cost is fairly high. The average cost of chemicals including shrinkage, for the period from May to December, 1932, was $5.64 per million gallons, divided as follows: alum $4.72; lime $0.60; and chlorine $0.32. These costs amount to more than $40,000 per year. Consequently savings effected by maintaining all chemical

dosages at minimum rates consistent with the best quality of product are of real importance.

The chemical treatment of the Ottawa River water involves change in the quantity of dissolved substances, particularly calcium, with resultant increase in hardness, although the raw water is so soft that the purified product can still be considered as a fairly soft water. Characteristic analyses of raw water, filter effluent and plant effluent are shown in table 2, giving a clear picture of the effects of the additions of alum and of lime.

THE ST. THOMAS PLANT

By W. C. Miller

(City Engineer, St. Thomas, Ont., Can.)

The filter plant at St. Thomas was put into service a little over a year ago. It treats a water that is secured by watershed storage of the runoff from a catchment area of about 60 square miles. An impounding reservoir holding approximately 350,000,000 gallons is located about half a mile upstream from the plant. This reservoir and the stream banks for some miles above has clay banks. Most of the timber has been removed and the catchment area is almost entirely cultivated agricultural land. The rainfall averages 37 inches annually, while the runoff usually is about 15 inches. The stream might be described as flashy and a flood flow is easily induced by a rain of one inch. The clay banks all along the stream are continually being cut away and the water after a heavy rain will carry an exceedingly fine turbidity of 3000 p.p.m. The writer has taken a sample in a jar after the grosser sediment has been removed by short settling and has observed no further clarification after a week of further quiescence. While the maximum depth of the reservoir is 30 feet the average depth is only 7. The water is thus very susceptible to changes in atmospheric temperature.

In ordinary years there is a long period in the summer when there is no outflow from the reservoir save what is being drawn for the use of the waterworks. On one occasion this dry period ran from early in June to late in November. The water is thus very susceptible to occurrences of tastes as a result of this long period of shallow storage.

The flow from the impounding reservoir to the plant is through the natural channel of the stream, being controlled by valves in the dam.

At the plant it is led into a settling reservoir having a capacity of 4,500,000 gallons where at ordinary rates it has an effective quiescent settling period of probably two days.

From this reservoir the low lift pumps pick up the water, it having been treated at the suction of the pumps with its dose of alum and a heavy dose of chlorine. It is then pumped through an aerator, a set of spiral flow conditioning tanks, settled, filtered and finally chlorinated.

The raw water is moderately hard (180 p.p.m.) and has a pH value ranging from 8.4 in the summer to 7.6 in the Spring. In the treatment of the water we usually try to maintain a pH of from 7.6 to 7.3. In the spring floods the turbidity of the water is very dark colored, almost black, accounted for by the fact that the watershed lies entirely north east of the city and the prevailing winds are from the south west. The smoke from the many railways shops is carried across this area and settled eventually on the snow where it stays till the spring thaw. This material does not present any particular difficulties in removal.

The most important part of the treatment is the least spectacular to the layman, the preparation of the water for filtration. The water is dosed with chlorine immediately on leaving the reservoir at a point where the raw water passes a port through which it might in case of emergency be conducted directly to the suction well from which the high lift pumps draw filtered water. The entire filter plant could if necessary be bypassed and the town served with chlorinated river water. This bypass or one like it has been in existence for 42 years and has in that interval been used only once. This was during a fire many years ago when the filtration capacity was insufficient. A better place for the introduction of the first dose would be after aeration, but this would involve some difficulties in operation and would leave the bypass port unprotected, although considerably less chlorine would be required. The initial dose of chlorine will run from 0.5 to 1.0 p.p.m.

The water is then admitted to the suction well of the low lift pumps and the required dose of aluminium sulphate is applied to the suction pipe. The low lift pumps elevate the water to the aerator through an effective head of 36 feet. When the plant was rehabilitated some twenty years ago the old pressure filters which before this had operated on the discharge side of the high lift pumps were converted into gravity filters and it was thought at that time that the

pressure filters had to have a head of about 30 feet in order to operate. The coagulation tanks were therefore built on the hill side adjacent to the plant and at a distance of about 600 feet thereform. In the recent rebuilding it was felt that, although the total capacity of the old tanks was somewhat less than the total daily capacity of the new filtration plant, there was sufficient investment in them to warrant their retention with some remodelling for greater efficiency.

The aerator consists of a perforated pipe though which the water is forced and permitted to fall a distance of 5 feet into the basin below. The aerator is part of the 1912 plant and was not changed in the latest rebuilding. A more effective design could probably be made now, but as the next coagulation unit will be built at a much lower level than the old one we did not change the aerator. The aerator may be bypassed at will and the water sent directly to the first chamber of the conditioning tanks. We have found, however, that the bypassing has very little effect on the treatment when the aeration is not required for odor removal. It is therefore used continuously. In the summer the water, as it leaves the aerator basin, is practically saturated with oxygen.

The passage of the water through the impellers of the pumps, its travel through 600 feet of pipe and its spraying through the aerator all combine to give the chemicals a very thorough mixing with the water.

The conditioning tanks are of the vertical spiral flow type a number of which have been built in Ontario during the past two years. As a matter of fact this was the first installation of this type to be placed in operation in Ontario on a plant scale, although not the first one that was designed. The normal detention period of 90 minutes, although rather long, was selected as a result of a prolonged experiment in a miniature plant that was used to obtain data during the preliminary investigations.

Each cell of the battery of tanks is about 12 feet square. The corners are filletted but not enough to destroy the squareness of the tanks. The water is admitted to each tank tangentially, alternately at the top and bottom, the withdrawing of the water from one cell being coincident with its admission to the next. The loss of head in the ports is adjusted so that a velocity is given the water sufficient to keep it in rotation during its stay in the cell. The square corners of the tanks interrupt the revolving motion sufficiently to create eddies in addition to the major circumferential rotation. The rota-

tion in each cell is a complicated process. The floc particles render the currents visible and resemble nothing so much as clouds of smoke rolling on themselves as they are directed around the outside of the tanks. The minor rotations entirely do away with any dead space that might be expected to form in the centre, except at the very bottom of the tank. This latter is evidenced by the collection of a small pile of sludge visible when the tanks are drained for their periodic cleaning. The location of these sludge deposits is interesting. They are not always found in the centre. Roughness of the side walls seems to deflect the dead area away from the centre. It is suggested that consideration might be given to the placing of a low cone of concrete in the bottom of the cells. The main current being around the outside, especially at the bottom, such a cone would tend to keep this sludge in suspension. The formation and coagulation of the floc is an interesting process to watch from cell to cell. There is a progressive removal of the turbidity from the water and in the last cell the water between the floc particles is quite clear. The alum dose will vary from 1.5 to 3.5 grains per Imperial gallon with a yearly average of 2.0 grains.

The conditioning tanks consist of twelve cells operated in batteries of six. Normally the two sets of six cells each are operated in parallel, but may be operated in series by the insertion of three small stop planks. In this way the velocities may be controlled somewhat should the consumption drop too far. Either set of cells may be placed first or either may be cut out of service altogether for cleaning or repair. The unit is in this way made very flexible in its operation.

The water is admitted to the settling basin through eight ports. The velocity of admission is dampened by steel drums open only on the upstream side and placed directly opposite each port. Any tendency for the water to travel sideways at the upper end of the basin is cut off by short concrete walls to guide the water out into the tank. All obstructions in the basins with the exception of a control row of columns were removed in the remodelling. In the old tanks there were several baffle walls which seemed to serve no good purpose and which made cleaning difficult. The settling period is three hours (theoretical) at the design capacity. The water level in the tank is controlled automatically so as to provide a uniform depth of water over the outlet weirs. This depth is sufficient to maintain a water level in the outlet troughs above the weir level, thus preventing the formation of a waterfall that might have a dis-

turbing influence on any remaining floc in the water, but not deep enough to prevent a uniform flow across all parts of the weir. The settling out of the floc is very complete and the water is uniformly of better quality leaving this part of the plant than it was at times after filtration before the plant was rebuilt. From 90 to 97 percent of the floc is removed in this tank. The basins normally require monthly cleaning during which time about two feet of sludge accumulate. The deposition is remarkably uniform. An idea may be obtained of the work done by the pretreatment plant by pointing out that during construction, the city supply was filtered and a better water obtained than previouly, while using only one half of the old filter plant that was previously overloaded. The filter runs were somewhat shorter, of course, during this period. The new conditioning plant was built and placed in service before any work was started on the construction of the filters.

In this plant it is imperative that the applied water should be uniformly of good quality. It was pointed out earlier that the coagulation units were located at a considerable elevation above the filters for economic reasons. This means that there has to be a continuous control of the water level on the filters to prevent flooding the operating floor. This control is effected by means of an automatically operated butterfly valve in a venturi throat. If any considerable quantity of floc were left in the water as it came to the filters, the throttling of the discharge through this valve would break up the floc and make the work of filtration much less effective. With the very complete deposition obtained in the pretreatment no difficulty from this source has thus far been experienced. As a result of the preliminary experiments before design was undertaken, it was decided that this factor did not present any difficulties, provided we could obtain a reasonably complete sedimentation.

The filter units themselves do not present any features that differ greatly from standard construction. The area of each unit is 396 square feet, giving at 1,000,000 gallons per day a rate of 110,000,000 gallons per acre per day or about 5 percent higher than the rate ordinarily adopted. The sand size is 0.55 mm. and has a depth of 28 inches, with a gravel bed of 20 inches graded in the customary manner. The wash water troughs are of ample size and will carry off a wash of as high as 60 inches without flooding. The customary wash water rise is 30 inches per minute. The wash water is about 2.5 percent of the filtered water.

The filter runs are terminated at 48 hours throughout the year. In times of heavy run off from the watershed this is probably the limit of the run. In the summer the runs could be extended to 72 hours, but we believe that the floc accumulation on the surface of the sand after it has been held for this long time will tend to cause a slight taste in the water.

The effluent from each filter is made visible to the operators by means of small white enamelled basins through which a small quantity of the filtered water is constantly passing. The bottom of these basins is a plate glass mirror. They are located directly below the operating tables and are inspected through on opening in the table top. They give a very sensitive indication of the turbidity of the water. They are not shown to the ordinary visitors, since the presence of a very minute quantity of turbidity that would not prevent the view of the bottom of the clear well through 13 feet of water will appear in the basins as a quite perceptible cloudiness.

After filtration the water receives the second dose of chlorine of from 0.3 to 0.4 p.p.m. and is then passed to the clear well for distribution to the mains.

The new plant was designed by Messrs. Gore, Nasmith and Storrie of Toronto, and was constructed under the supervision of the writer. The contractors are to be congratulated on the excellence of their workmanship.

THE WINDSOR PLANT

By J. Clark Keith

(Chief Engineer, Essex Border Utilities Commission, Windsor, Ont., Can.)

In the general effort to meet the increasingly more discriminating demands of the public for a water supply that is safe, attractive and reasonable in cost, the filtration plant located at East Windsor, which supplies the communities along the Detroit River commonly called the Border Cities, has met with some measure of success.

Problems, some peculiar to this district, others common to many filtration plants, have been encountered and remedial measures have been applied. The degree of success enjoyed can best be measured in a study of the annual operation reports. Wastage of materials and equipment has been studiously avoided and every effort has been made to permit the existing equipment to render efficient service.

A major feature in the general operating program has been the assembly of a set of records by which the relative performances and costs of the varied divisions of operation may be gainfully studied. These records have been built up in some detail with the thought in mind that they would provide a ready and accurate answer to every reasonable question which might be asked regarding the operation of the plant. They have proven particularly valuable during the past three years, the Depression Years, when it has been essential that every item of expenditure be justified and vital to the proper operation of this public utility. The information contained in these records ranges from the hourly reading of the operators to the annual summaries supplemented by much miscellaneous data.

Frazil ice has been the source of some inconvenience to the normal operation of this plant. It appeared during the first winter of operation 1926–1927, and again to a lesser degree in the winter of 1927–1928. The most serious occurrence came in February, 1933 and on this occasion, as on all others, relief from the trouble was secured by placing the intake under a low pressure and "blowing off" the plug of ice which had formed at the bell mouth of the intake. The plant is so designed that the flow from the low lift pumps can be utilized for this purpose. It has been observed that certain general conditions have prevailed on each occasion, viz., westerly winds, air temperature below 15°F., raw water turbidities below 30 p.p.m. and the absence of an ice covering over the Detroit River for a distance of approximately 3 miles above the intake. It has been observed also that with winds and temperature favorable and *with turbidities of 50 to 60 p.p.m.*, or an ice covering on the River, frazil ice did not form. It is then apparent that these latter conditions are factors in preventing the formation of this type of ice. It is of special interest to note that the relief measures, as incorporated in the plant design, have proven sufficient to meet every demand made upon them.

Objectionable tastes appeared in the treated water in December, 1930, and their removal was made possible by the introduction of the chlorine-ammonia treatment of the raw water. The cause of these disagreeable "Iodoformic" tastes has not been definitely determined, but it is known to be a general condition throughout the Lake St. Clair and Detroit River District. The dosages applied were chlorine, 1.5, and ammonium sulphate (25% available NH_3) 3.0 pounds per m.g.

Raw water turbidities ranging in concentration from 3 to 400

p.p.m. have proven to be the greatest variable factor encountered in the operation of this plant. These range from extremely fine semi-colloidal yellowish clay particles to coarse sandy grains; in the "run off" seasons, particularly close attention must be paid to the chemical dosages applied to cause flocculation. These dosages range from 0.3 to 3.0 g.p.g. (1930–1932 records). No definite schedule of dosages may be prescribed, but it is the duty of the operator to make certain that the dosage is sufficient and not wasteful. Comparative data as to the raw water turbidities observed along the Canadian Shore of the Detroit River and the alum dosages applied are shown in table 1.

TABLE 1

Comparison of raw water turbidities

BETWEEN	NUMBER OF DAYS					
	1927	1928	1929	1930	1931	1932
p.p.m.						
0– 10	216	79	92	92	133	9
11 –20	48	147	112	119	98	79
21– 50	58	88	86	98	107	156
51–100	27	34	33	36	27	85
101–200	15	15	24	14		35
201–400	1	3	18	6		2
400+						
Total days	365	366	365	365	365	366
Average raw turbidity	24	30	44	35	24	49
Average alum dosage, g.p.g.	0.8	0.8	0.9	0.9	0.5	0.9

Note: Parts of year 1928, 1929 and 1931, lime and iron used as coagulants. "Pre-Chlorination" from May, 1930 to date.

A study of the plant records shows that material reductions in the cost of coagulating chemicals, per unit of turbidity, have obtained since the introduction of the "pre-chlorination" program.

Mixing and coagulation, as well as settling, are fixed features in this plant. It has been evident because of the wide range in types of turbidities that some flexibility in the time and violence of both the mixing and coagulation would be desirable and would permit of more economical chemical treatment. During the past two years, and particularly during the latter part of 1932, attention was directed to the possibility of using the filters to remove a higher percentage of

the turbidity. In many instances it is possible, by reducing the alum dosages slightly, to carry over to the filters a greater percentage of the material in suspension *without* affecting the length of filter runs, the clarity of the effluent or the general condition of the filter bed. No general rule has been applied and each effort was treated as a new experiment. The result of these efforts has been a saving in chemical costs. It is believed that close attention to this very important phase of purification will result in worth-while economies. A record of filter performance is shown in table 2.

In the design of this plant, described in some detail in previous papers, the filter beds are arranged in two rows which are separated

TABLE 2

Comparative data on filter runs

YEAR	FILTER SERVICE TOTAL HOURS	PERCENT OF TOTAL AVAILABLE FILTER HOURS	AVERAGE RATE FILTRATION	TOTAL FILTER RUNS	AVERAGE MILLION GALLONS BETWEEN FILTER BACK-WASHES	AVERAGE LENGTH OF FILTER RUNS	
			m.g.a.d.			*hours*	*minutes*
1927	27,604	64	117	2,023	2.13	13	09
1928	28,901	66	112	1,859	2.33	15	33
1929	30,574	70	114	1,902	2.45	16	05
1930	28,287	65	116	1,466	3.09	19	20
1931	23,994	55	117	882	4.34	27	10
1932	24,758	56	100	716	4.70	34	35

Note: Pre-chlorination, May, 1930. Pre-ammoniation, Jan., 1931.
Time lost per filter backwash—average 25 minutes.
Time lost for general filter maintenance—6 percent total available time.
Area of filter unit—1400 sq. ft. (2 filters = filter unit).

by the pipe galleries and deck, and the effluent from each pair of beds passes through a single controller tube and valve. In normal operation the beds are taken out of service in pairs, washed independently and returned to service simultaneously. Wash water is supplied by two electrically driven pumps located in the low lift pumping station.

Electrical power costs are based on the peak demand and, in an effort to reduce this peak, an interval of approximately 25 minutes was ordered between the backwashes of the single beds. This delay permitted the demand meter to "cool off" and a material reduction in the peak demand resulted.

This change in operating program became effective May 1, 1932,

and was made possible by the greatly increased lengths of filter runs which prevailed in 1932 and through decreased plant output. As a result of this measure, power costs were reduced from 0.82 in 1931 to 0.78 cents per K. W. Hr. in 1932 and a saving of approximately 5 percent or $60.00 per month was effected. Greater savings are expected in 1933 when these measures will be applicable for the full 12 months.

An important phase of routine operation in this plant is the monthly inspection of the filter beds. The presence of mudballs, evidence of

TABLE 3

Filter bed inspection

Filter sand inspection—covering the condition of the top 6 inch layer of filter sand in July, 1932.

Specific gravity (indication of coating). New sand—specific gravity—2.646

	SPECIFIC GRAVITY		DEPTH OF STAINED SAND—INCHES	
	August, 1931	July, 1932	August, 1931	July, 1932
R-1	2.637	2.632	½+	1 ±
L-1	2.632	2.625	1 +	1 ±
R-2	2.627	2.613	4	4
L-2	2.620	2.622	2½	3
R-3	2.625	2.623	2	1½
L-3	2.616	2.611	5	4
R-4	2.615	2.617	5	4
L-4	2.618	2.622	3½	3
R-5	2.640	2.634	Nil	Nil
L-5	2.640	2.637	Nil	Nil

Note: In general it may be stated that the specific gravity tests indicate a very slight increase in the coating of the sand grains while the staining of the grains appears to be on the decrease.

cracking, lumping and excessive shrinkages from the side walls, are sought and measures to correct any unusual and undesirable condition are immediately applied. It is felt that these examinations have prevented these conditions reaching serious proportions, the treatment of which would be costly. These records tell a progressive story of the general filter bed conditions. Specific gravity determinations of the sand are made yearly as a check on the coating of the sand grains. Table 3 (taken from 1932 summary) is presented to show the results observed in 1931–1932.

The general treatment accorded to the raw water, which includes

pre-chlorination and pre-ammoniation, is keeping the filters in a reasonably clean condition. An advantage and a proof of the efficacy of this treatment is particularly evident from the observations made in units R & L-5. The sand in this bed was purchased subsequently to that in the balance of the beds and is slightly coarser. The pre-chlorinating program was in effect before the sand was purchased and it shows no evidence whatever of staining.

The goodwill of the public served may be considered an intangible asset of every filtration plant. Its existence is indicated by the absence of complaints and is secured by operating this utility on a reasonably economical and efficient basis. It has been found helpful in our effort to gain the goodwill of the residents of the Border Cities to welcome them as visitors to the Filtration Plant. To treat these visitors with courtesy, to give them what information they may seek, and to present the story of filtration in lay terms is an integral part of the operating program of this plant.

(Presented before the Canadian Section meeting, March 23, 1933.)

PUMP INFECTION UNDER NORMAL CONDITIONS IN CONTROLLED EXPERIMENTAL FIELDS[1]

By Elfreda L. Caldwell and Leland W. Parr

(Field Research Laboratory, Alabama State Department of Health, Andalusia, Ala.)

Houston (1912) first noted a lactose-fermenting, indol-positive organism, the so-called "leather bacillus," growing on the washers of a tap of one of the pressure mains of the Metropolitan Board Works, and causing falsely positive results in tests of the water for the presence of organisms of the colon-aerogenes group. Greer (1928) and Greer and Kells (1929) showed that the leather washers from four sampling pumps in the tunnels of the Chicago Water Supply System and four washers from private wells giving high coli indices at variance with the quality of the water, also yielded members of the colon-aerogenes group. Spaulding (1929) found aerogenes growing abundantly on leather packing, and called attention (1931) to the fact that the jute packing in cast iron pipes in mains might possibly serve as a source of organisms giving positive indices in B. coli tests. Recently Leahy (1932) reported a cotton rope as a focus of contamination in a swimming pool.

The lack of correlation between the reports of sanitary surveys of water plants and the bacteriological findings in the examination of private water supplies, and the variation in results of examinations of plant samples and tests of the distribution system tend to discredit unjustly the reliability of B. coli tests as indices of pollution. Knowledge of the possible origins of aftergrowths offers a basis for the proper evaluation of bacteriological findings and for the eradication of misleading sources of positive colon-aerogenes findings. In the belief that further data on the incidence and conditions of pump infection under normal conditions may be of value in the consideration of these points, we offer this paper.

[1] The studies and observations on which this paper is based were conducted with the support and under the auspices of the International Health Division of the Rockefeller Foundation.

In studying the contamination of water supplies in controlled experimental fields, numerous pipe wells, protected from surface contamination by concrete construction, were driven to various depths and in various positions with respect to experimental latrines. These wells were equipped with force pumps provided with high grade leather washers. Approximately 150 of the wells were tested frequently, some daily, over periods of time varying from two years to several months. Routine examination involved the collection of three samples while pumping forty gallons; in special investigations, sample volumes up to 2,000 gallons were withdrawn. Organisms of the colon-aerogenes group were recovered and were classified by means of methyl red, indol, and citrate reactions into B coli, B. aerogenes, and intermediate types (Koser, 1924). Bacteriological and chemical analyses indicated that a large proportion of the wells were offering good water; others were receiving chemical, but not bacterial, contamination from the latrines; and some were yielding both chemical and bacterial pollution in varying degrees.

OCCURRENCE, CONDITIONS, AND TYPES OF NORMAL INFECTIONS

In 1929–1930 two wells yielded B. aerogenes in practically every test volume for five months, and two other wells consistently delivered indol-positive B. aerogenes for more than a year. Epidemiological data and chemical and historical evidence, as well as the type of organisms recovered, eliminated the possibility that the organisms had derived from ground water contaminated either from the latrines or from the surface; but their exact source could not be demonstrated experimentally. Houston's work had not then come to our attention.

In September, 1931, one of four wells (No. 6), situated at a distance of 25 feet from an experimental latrine, delivered samples consistently positive for B. aerogenes in all 10 cc. and most 1 cc. test volumes in six consecutive examinations, although its companion wells were yielding no lactose fermenters. When a pump from one of the proved control wells (No. 8) was transferred to No. 6, the water was found to be free from colon-aerogenes organisms. The leather washers were removed from Pump S (which had previously been on Well No. 6) to sterile distilled water. From one washer placed in fresh water at the end of a week, a small piece (5 x 7 cm.) was transferred three weeks later to a jar containing 1400 cc. of sterile water. After the jar was shaken twenty-five times, 10,000 B. aerogenes per cubic centimeter were recovered. It was clear that the organisms previously

recovered had not derived from the ground water, but from the pump in which infected washers had served as culture media for the multiplication of organisms having the appearance and reactions of B. aerogenes.

New washers were substituted for the old in Pump S. The pump was chlorinated after handling and was transferred to the control well, No. 8. In the first examination on the following day all samples were negative. In subsequent examinations a week later all samples were positive. By interchanging pumps and then sampling, it was demonstrated that the ground water flowing through Well No. 6 and Well No. 8 was free from colon-aerogenes organisms, but that the water was acquiring B. aerogenes in passing through the revamped Pump S. The substitution of new washers and the addition of hypochlorite had not completely eradicated the infection of the pump. With due precautions for aseptic handling, parts of Pump S were interchanged with parts from control pumps. Tests then revealed that the plunger with its pull valve and the check valve with its washer, when transferred from Pump S to separate control pumps, contaminated every sample taken during routine examination. With their removal the heaviest foci were eliminated. Pump S, now supplied with entirely new parts from proved control pumps, was, however, not entirely free from infection; it yielded the type organism in one sample in two of nine 10 cc. test volumes. Within six days Pump S, transferred to a new control well, was delivering B. aerogenes in every 10 cc. volume and in half the 1 cc. volumes; in subsequent examinations over a period of three weeks it was found to be delivering the organism in practically every 1 cc. volume.

Pump S had been in more or less constant use for two years. Not only the plunger, but the barrel of the pump was encrusted with rust. Leather washers in constant use became frayed and minute shreds cling to the rough surfaces of used pumps, so that despite substitution of new washers for old, all foci were not obliterated. A few B. aerogenes which survived chlorination—too few in number to contaminate 10 cc. test volumes—readily attacked the new washers and rapidly built up heavy foci. Houston remarked on the "susceptibility" of certain leathers, since, in laboratory experiments, new washers were not readily attacked. Greer noted "recurrence" of contamination in the same sampling pump subsequent to removal of washers, which was finally controlled by the institution of pumps with all-metal parts. His brief statement implies the attack of new

washers by organisms from the water. Our experience suggests rather a recrudescence of growth of the type organisms remaining in the pump.

Pump infection was not a rare occurrence. In addition to four such infections noted in 1929–30, seven, including that of Pump S, were observed between September, 1931, and August, 1932, and the infection was experimentally demonstrated on control wells in a control field. The infections were not confined to one type of organism. Two pumps were infected with pseudomonas, the other five with organisms of the colon-aerogenes group. Two of the latter pumps were also infected with pseudomonas. That is, of 150 wells frequently tested, eleven, or 7.3 percent, showed pump infection.

Five infections with B. aerogenes (two indol positive) derived from wells offering good water; three infections, one each of the type or-

TABLE 1

Incidence of pump infection and classification of organisms present

INFECTED PUMPS			REACTIONS			CLASSIFICATION OF ORGANISMS
1929–30	1931–32	Total	Methyl Red	Indol	Citrate	
2	2*	4	−	−	+	B. aerogenes
2	1	3	−	+	+	B. aerogenes, atypical
0	2	2	+	−	+	Intermediate
0	2	2				Pseudomonas only

* Pseudomonas also.

ganism listed, came from wells receiving chemical pollution but not latrine organisms; one intermediate and the two pure pseudomonas infections originated in wells receiving fecal contamination. Houston, in laboratory experiments, had not found that "susceptible" washers readily became contaminated with the "leather bacillus" from raw Thames water or water containing 1.0 percent of crude sewage. In our fields, under normal conditions of use, four of nine colon-aerogenes infections, as well as three pseudomonas contaminations, came from wells drawing sewage products. Infection was not confined to old pumps. Comparatively new pumps, in use for only a few weeks, also became contaminated.

The fermentation of various sugars and other cultural reactions by the type organism involved in the colon-aerogenes infections were secured for comparison with the "leather bacillus" of Houston. It is

not possible from these reactions to identify any of our pump-infecting organisms with the "leather bacillus" which differs, however, from our B organism only in its reaction to dulcite.

TABLE 2

Comparison of reactions of organisms from pumps S, B, and C and of "B leather" to various substances

ORGANISM	MOTILITY	GELATIN	INDOL	DEXTROSE	LACTOSE	SACCHAROSE	MALTOSE	MANNITE	ADONITE	DULCITE	INULIN	INOSITE	SALICIN
From pump S....	−	−	−	+	+	+	+	+	+	+	−	+	+
From pump B....	−	−	+	+	+	+	+	+	+	+	−	+	+
From pump C....	−	−	−	+	+	+	+	+	+	−	−	+	+
"B. Leather"	−	−	+	+	+	+	+	+	+	−	−	+	+

TABLE 3

Normal recovery of type organisms from pumps S, B, and C

PUMP INFECTION	DATES (1931-32)	NUMBER OF EXAMINATIONS	NUMBER OF SAMPLES	GAS POSITIVE, 24 HOURS			GAS POSITIVE, 48 HOURS			COLON-AEROGENES POSITIVE	PLATE DATA	
				3 10 cc.	2 1 cc.	2 0.1 cc.	3 10 cc.	2 1 cc.	2 0.1 cc.		Number positive	Total count
Aerogenes pump S	9:15–28	6	18	11	3	1	54	26	18	18	11	97
Aerogenes										13*		
Indol +	9:15–10:30	11	33	0	0	0	73	40	24	20	31	473
pump B	11:10†	1	16	0	0	0	39	15	1	1*	8	16
										15		
Intermediate	1:8–27	6	18	27	13	10	54	36	35	18	18	769
pump C	4:26	1	3	9	2	1	9	2	2	3	3	6
	6:6–7	2	6	10	3	0	12	3	0	6	3	9

* Pour plate only.

† 510 gallons pumped.

The normal recovery of these type organisms (for variants, see Parr and Caldwell, 1932) from pumps B, C, and S when infection was well established, is compared in table 3.

The indol-positive B. aerogenes infecting Pump B produced no gas

in twenty-four hours and frequently none in forty-eight hours, so that recovery of the organisms from approximately one-third of the samples was possible only from pour plates. The slow formation of gas suggests that the organisms may be of the soil type. The B. aerogenes from Pump S produced gas in forty-eight hours in all 10 cc. volumes, although in only one-fifth of the samples did it occur in twenty-four hours. This delayed formation of gas may be due to the complicating pseudomonas infection. In pure culture, B. aerogenes formed gas within twenty-four hours and produced a somewhat different type of growth on agar than did the indol-positive B. aerogenes. The intermediate type of organism from Pump C was recovered consistently from broth in which gas production was more typical of the fecal colon group. In pure culture it produced gas with uniform promptness within fifteen to twenty-four hours. The organism also showed a tendency to more luxuriant growth on the washers. With fairly frequent examinations in January, recovery was obtained in practically every 0.1 cc. test volume, and although several months had elapsed since the previous testing the organism was found in all 10 cc. quantities in April, and again in June, six months after the initial demonstration.

ARTIFICIAL INFECTIONS

Under natural conditions no pump was found to be infected with organisms giving the reactions of fecal B. coli. Greer and Kells (1929) mention that one sampling pump and the washer of a fire hydrant were found to be yielding B. coli, but the reactions determining classification were not stated.

Sterile pumps were artificially infected and tested upon control wells, in the same way as were the naturally infected pumps. The following cultures were used:

(A) 2 liters of a mixed culture of B. coli (field) and B. prodigiosus, poured into a pump having a slight residual infection with B. aerogenes (S);
(B) 1 liter of a culture of B. coli (field);
(C) 700 cc. of a saline suspension of human fecal B. coli;
(D) 700 cc. of a saline suspension of human fecal B. aerogenes.

Routine examinations were begun on control wells twenty-four hours after inoculation of the cultures. The results are shown in table 4. B. coli was recovered only once, in the first sample from the pump in Experiment 1. B. prodigiosus persisted throughout the greater part of the period of investigation. They gradually dimin-

ished in number, at first being recovered in approximately half the streakings, in only 7 percent by the ninth examination, and not at all in the last examination. The surprising rejuvenation of the residual B. aerogenes is revealed in the recovery in the first week, showing hundreds, and occasionally thousands, per cubic centimeter. It would seem that B. coli could not get a foothold in competition with the other two organisms; that B. prodigiosus put up a losing fight for survival; and that additional foot supply had stimulated a vigorous growth of residual B. aerogenes.

The same pump sterilized in the autoclave and inoculated with a broth culture of fecal B. coli, derived from ground water contaminated from a latrine, produced gross contamination of water samples during twenty-seven days (Experiment 2). Upon reinoculation of the sterilized pump with a saline suspension of human fecal B. coli (Experiment 3), on February 9, the number of organisms recovered was smaller than in Experiment 2 in three successive examinations, but by the fourth day the yield of B. coli approximated the number recovered when the broth culture had been added. Although six weeks had elapsed between the examinations made in March and those made in April, B. coli appeared in every sample in a high proportion of 0.1 cc. test volumes. The sterile pump inoculated with human B. aerogenes (Experiment 4) yielded the test organism in every sample in 90 percent of 0.1 cc. quantities during seventy-one days of testing.

TABLE 4

Results of artificial infection of sterile pumps, as tested on control wells

Experiment number	Culture injected	Dates (1931–1932)	Number of examinations	Number of samples	Gas positive			Positive			Pour plate data	
					3 10 cc.	2 1 cc.	2 0.1 cc.	*B. aerogenes*	*B. coli*	*B. prodigiosus*	Number positive	Total count
1	A	12:13–1:9	13	36	108	70	64	36	1	20	33*	8464*
2	B	1:15–2:5	9	29	87	58	58	—	29		28	4056
3	C	2:9–2:11	3	12	33	15	6	—	11	—	4	15
		2:12–4:22	4	17	51	32	27	—	17		16	1638
4	D	2:16–4:28	8	24	72	44	43	24	—	—	22	4209

* *B. aerogenes* recovery

These experiments suggest the possibility that leather washers of

pumps can become infected with B. coli and can yield the organism consistently over a period of months.

EFFECTS OF VARYING CONDITIONS

Chlorination. In 1929–1930 attempts to destroy infecting organisms by the addition of hypochlorite solution (45 p.p.m.) to the wells and pumps had failed. The organisms lessened in number or disappeared for a brief period, but they later reappeared. A somewhat similar situation was found to exist in the case of Pump S. Further attempts to sterilize infected washers directly in the pumps were not successful. After the addition to Pump B (table 2) of strong hypochlorite (450 p.p.m.), which was left in contact with the pump for one and a half hours, all samples were positive upon routine examination in 1 cc. volumes. After contact for twenty-four hours, all samples were negative on the first examination; increasing multiplication was evident in two successive pulls; and by the fourth day all samples were again yielding the type organism, indol-positive B. aerogenes. After substituting new washers for old and chlorinating again, pump infection was not evident in test volumes for two successive examinations, but in the third it was clear that residual organisms had attacked the new washers and were growing more prolifically than previously.

Cleaning. When, however, old infected washers were removed from Pump B, and the pump was thoroughly cleaned in a soda vat, all rust spots eliminated with electric brushes, new washers inserted, and the entire mechanism chlorinated after handling, no infection was found even after repeated testing on the well that had been used in previous chlorination tests.

Heat. Sterilization could, of course, readily be effected by heat. Boiling water killed the contaminating organism in an infected pump after contact for from ten to thirty minutes.

Drying. A pump from which B. aerogenes had been recovered in 0.1 cc. volumes in routine examination, was removed from the test well, drained of water, and allowed to stand at room temperature. Although greatly reduced in degree, the infection was still present when the pump was tested sixteen days afterward. In later tests on control wells, contrary to our experience with other infections, the type organisms failed to multiply, appearing only in occasional samples in scattered volumes. They disappeared entirely in six weeks. In drying, the washers had shrunk so that the check valve

failed to keep the pump primed between tests, causing the infecting organisms gradually to succumb.

Freezing. The gross contaminations of two wells with B. aerogenes, first observed in late August of 1929, suddenly and simultaneously disappeared late in January, 1930, although the wells are in different locations. Two other wells yielding indol-positive B. aerogenes, in which infection first appeared in the spring of 1930, continued to produce the type organisms until the wells were abandoned. The disappearance of infection in two wells and its persistence in two others were puzzling. Scrutiny of old records, however, suggested that these variations might have been due to temperature conditions.

Pumps S and B, yielding B. aerogenes and indol-positive B. aerogenes as previously described, were therefore subjected to freezing for twenty-four hours. They were submerged in the freezing mixture of an ice plant with the temperature kept at 9.4° below zero, Centigrade. The effect was somewhat analogous to that of chlorination: freezing killed most of the infecting organisms, but a few survived to begin a new cycle. No organisms were recovered at the first examination; multiplication was retarded for two or three days; but by the fourth or fifth day growth was again vigorous. Examination of the water within the pump and of the cut-off attached to it, during freezing, made it clear that freezing had in fact killed the greater proportion of the organisms and had not merely squeezed them out into the water ordinarily flushed out of the pump before sampling.

These experiments explain the anomalous situation described. The winter of 1930 had been unusually severe. The disappearance of infection followed a period of five days during which the minimum temperatures ranged from 6.9° to 4.4° below zero, C. Successive freezing, together with the thawing of the frozen pumps, had completely eradicated the foci. The winter of 1931, however, was so mild that these processes were not brought to bear on the two infections with indol-positive B. aerogenes, which persisted as long as the pumps were in use.

The results obtained by freezing pumps artificially infected with fecal B. coli and B. aerogenes showed interesting variations. In both cases some reduction occurred in the numbers of the organisms, but this was minimal; the organisms were present in every sample in practically all 10 cc. test volumes. B coli, instead of gradually building up a new cycle within a week's time, showed a progressive dimi-

nution in numbers, appearing in only one of twelve 10 cc. volumes on the third day. The infection was still present ten days later, but there was no evidence of rejuvenation. B. aerogenes, however, although its growth was retarded slightly for two days, was multiplying rapidly by the fourth day.

The variation in response to freezing of the field forms and fecal forms of the colon-aerogenes group, suggests a biological variation that invites further study. (Caldwell and Parr, 1932.)

CONCLUSIONS

In our study we found that in wells in which the water was contaminated through pump infection the contamination was greater than that in wells otherwise polluted, with the exception of those in the direct pathway of flow very close to a fecal source, under optimum soil conditions. After some experience, pump infections were readily detected, since the recovery of organisms when such infection was present differed from that suggested as possible by attendant conditions—epidemiological, biological, or chemical. Interchange of pumps, or sterilization of infected pumps by heat, and subsequent testing on the same wells and on control wells, afforded prompt corroboration of suspicion.

In general, our results stress the fallacies possible in the interpretation of the bacteriological analyses of water samples in the absence of complete data for evaluation. They emphasize the fact that, in analyzing persistent pollution of piped water supplies, interpretation should not exclude consideration of contamination by the distribution system. The appreciation by the sanitarian of the possibilities of pump and pipe infections, and the conditions influencing their inception and persistence, should aid in the correct appraisal of waters tested and should result in the use of parts and processes free from the possibility of such infection.

SUMMARY

In a study of the pollution of ground water from latrines in controlled experimental fields, frequent examination of 150 test wells disclosed infection in eleven pumps (7.3 per cent). The contaminating organisms included pseudomonas and members of the colon-aerogenes group, namely, B. aerogenes, indol-positive and indol-negative, and intermediate types. Pumps were artificially infected with human fecal B. coli and with B. aerogenes and were subjected to natural

conditions for tests. The probable causes of recurrence of infection are suggested, and the effects of chlorination, cleaning, drying, freezing, and the application of heat are discussed.

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THE ORTHO-TOLIDINE TEST FOR CHLORINE

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This test, first proposed by Phelps in 1913 and reported by Dittoe and Van Buskirk (1) was developed by Ellms and Hauser (2) to a point where it is almost universally applicable in the control of water chlorination. From time to time, papers (3, 4) have appeared pointing out limitations of the method in the presence of interfering substances and restrictions in the use of permanent standards.

The present paper includes new evidence on the chemistry of the reaction; directions for the preparation of "zero-demand" water and chlorine standards; a reëxamination of the original permanent standards with spectrophotometric equipment; a study of the reaction of chloramine with o-tolidine; a study of the interactions of chlorine, manganese ions, and o-tolidine; a method for the determination of manganese in water; and a new method for estimating chlorine in the presence of manganese.

NATURE OF THE ORTHO-TOLIDINE REACTION

Ortho-tolidine is dimethyl benzidine and has a melting point of 129°C. It is soluble in alcohol and in ether, but only slightly soluble in water. Being an amine it dissolves readily in acids forming the water soluble salt of the base. The hydrochloride reacts with minute amounts of free chlorine and of hypochlorites to produce solutions of a yellow color. Oxidizing agents produce a similar coloration when treated with the hydrochloric acid solution of the reagent. Whether this color reaction is due to the chlorination of the amine or to oxidation, as suggested by Ellms and Hauser (2), was investigated during this study. Owing to the fact that the hydrochloric acid of the reagent could produce free chlorine when reacting with the oxidiz-

ing agents, there is ground for the belief that the color production may be due entirely to the entrance of chlorine atoms into the ortho-tolidine rings. On the other hand a water solution of chlorine is an oxidizing agent and hence it may be argued that such solutions in common with hypochlorites and other oxidizing agents produce the coloration by the process of oxidation.

Monfort (5) presented experimental evidence favoring the belief that the color production is essentially due to oxidation and lists a number of oxidizing agents including manganic and permanganate salts which are capable of producing the coloration when treated with orthotolidine. Hopkins (6) points out that such salts produce coloration with the reagent in proportion to their states of oxidation and that the reaction is not fundamentally a chlorination since he could produce the coloration in the absence of hydrochloric acid and chlorides. Apparently the above mentioned workers investigated only the qualitative character of the reaction.

The preparation of some of these standard manganese solutions involves some difficulties and since they are of considerable importance in several parts of this investigation, the methods used are given below.

(a) *Manganic salts.* A standard manganous solution containing 0.05 mg. per cubic centimeter was prepared by dissolving 143.8 mg. of pure potassium permanganate in approximately 100 cc. of water, after which 10 cc. of six normal sulfuric acid and 400 mg. of sodium bisulfite were added, the latter serving to reduce the permanganate manganese to the bivalent condition. After reduction the solution was boiled gently to expel sulfur dioxide and then cooled and made up to a volume of one liter, each cubic centimeter of which contained the amount of manganese indicated above, namely, 0.05 mg. Using this standard solution, standard manganic solutions were prepared by introducing measured volumes of the former into 80 to 85 cc. portions of distilled water saturated with dissolved oxygen. These solutions were next made alkaline by addition of a few drops of potassium hydroxide solution (700 g. per liter) and allowed to stand 10 minutes. By this means the manganous salt is oxidized to the manganic (Mn^{+++}) condition.

The solutions were acidified by the addition of six normal sulfuric acid and each diluted to 100 cc. Separate 100 cc. portions of the standard manganic solutions were treated, in one case with 0.1 per cent ortho-tolidine in 10 per cent HCl (7) and in another with 0.1

per cent ortho-tolidine in 10 per cent phosphoric acid. The resulting colors were compared with those produced by the action of ortho-tolidine in HCl on 100 cc. portions of chlorine solutions of equivalent concentrations. They were found to be the same.

Thus, it is apparent that chlorine and manganic salts, in equivalent oxidizing concentrations, produce the same intensity of color with

TABLE 1

Comparison of ortho-tolidine reaction on chlorine and on manganic salts in equivalent concentrations

(Results in parts per million)

CHLORINE ADDED	MANGANIC Mn ADDED	CHLORINE EQUIVALENCY OF Mn ADDED	CHLORINE EQUIVALENCY FOUND BY	
			O-tolidine-HCl reagent	O-tolidine-H_3PO_4 reagent
0.30			0.30	
0.50			0.50	
	0.50	0.32	0.30	0.30
	0.75	0.48	0.50	0.50

TABLE 2

Comparison of ortho-tolidine reaction on chlorine and on permanganate in equivalent concentrations

(Results in parts per million)

CHLORINE ADDED	Mn AS MnO_4^- ADDED	Cl EQUIVALENCY OF Mn ADDED	CHLORINE EQUIVALENCY FOUND BY	
			O-tolidine-HCl reagent	O-tolidine-H_3PO_4 reagent
0.7			0.7	
0.8			0.8	
1.0			1.0	
	0.22	0.70	0.7	0.7
	0.247	0.79	0.8	0.8
	0.308	0.99	1.0	1.0

ortho-tolidine and that the manganic compounds, in the absence of HCl and chlorides, produce, with ortho-tolidine in phosphoric acid, a like degree of color.

(*b*) *Permanganates.* A 0.005 N solution of potassium permanganate was prepared and from this by dilution a 0.0005 N solution. Measured volumes of this solution were diluted to 100 cc. and separate portions were treated in one case with ortho-tolidine in HCl and in

another with the same reagent in phosphoric acid. Equivalent quantities of chlorine in 100 cc. volumes were also treated with the ortho-tolidine in HCl reagent. As in the case of the manganic salts, it is also true here that chlorine and permanganate in equivalent concentrations produce quantitatively equal color intensity with ortho-tolidine regardless of whether the reagent is made up with HCl or H_3PO_4.

It is apparent, therefore, that the ortho-tolidine color reaction, in the case of these two oxidized forms of manganese, is an oxidation reaction and that the intensity of color is quantitatively the same as that produced by chlorine in equivalent concentration.

PREPARATION OF CHLORINE STANDARDS

Chlorine was generated by the interaction of calcium hypochlorite and dilute hydrochloric acid. The resulting gas was led into am-

TABLE 3

Chlorine demand of ammonia-free water

TUBE NUMBER	1	2	3	4	5	BLANK
Volume of NH_3-free water used, cc	100	100	100	100	100	100
Volume of 10 p.p.m. Cl_2 solution added, cc	0.1	0.2	0.3	0.4	0.5	0
Volume of ortho-tolidine added, cc	1.0	1.0	1.0	1.0	1.0	1.0
Resulting tint	None	None	None	Yellow	Yellow	None

monia-free water contained in a glass stoppered bottle and stored in the dark. A solution containing from 650 to 700 p.p.m. of chlorine resulted. This was analyzed by iodimetric means using potassium iodide and a standard sodium thiosulfate solution. From this concentrated solution weaker ones were prepared (10 to 13 p.p.m.) by diluting with ammonia-free water. This solution was likewise stored in the dark and was frequently checked by iodimetric means using N/200 sodium thiosulfate. Using this latter chlorine solution, standards for the ortho-tolidine reaction were prepared by dilution with "zero water," that is, water having no chlorine consuming capacity. It was found that both ordinary distilled water as well as that obtained by distillation from potassium permanganate (ammonia-free) often had a considerable chlorine demand capacity.

It is apparent from table 3 that a 100 cc. portion of the particular ammonia-free water used consumed 0.3 cc. of a 10 p.p.m. chlorine solution.

To insure the preparation of a "zero water," ammonia-free water was over-dosed with a chlorine solution after which the excess chlorine was volatilized by 30 minutes boiling. Experiment showed this to be a minimum time to insure complete removal of chlorine. When 100 cc. of this boiled solution was treated with two drops of a 10 p.p.m. solution of chlorine and tested with 1 cc. of the ortho-tolidine reagent, a noticeable yellow coloration resulted. "Zero water" was used in making all standard chlorine solutions.

The amounts of chlorine in parts per million indicated in table 4 were introduced into portions of "zero water" contained in 100 cc. Nessler tubes after which the solution was diluted to the mark by adding "zero water" followed by one cc. of the ortho-tolidine reagent. The full color developed in about eight minutes. These standards were compared colorimetrically with the $K_2Cr_2O_7$-$CuSO_4$ permanent standards next described.

Two concentrations of potassium dichromate solution were used, one containing 0.25 g. per liter for the ranges up to and including 0.10 p.p.m. of chlorine, while the second used on the higher ranges contained 2.5 g. per liter. The first solution also contained 0.1 cc. concentrated H_2SO_4 while the second contained 1.0 cc. The dichromate used was checked for purity by iodimetric titration against sodium thiosulfate which in turn was titrated iodimetrically against potassium permanganate solution which was standardized against U. S. Bureau of Standards sodium oxalate as the ultimate standard. The analysis showed 0.15 per cent impurity in the potassium dichromate. The solutions were withdrawn from the stock bottles by means of all-glass syphons and were measured from glass stopcock burets. The copper sulfate solution contained 1.5 g. per liter of the salt and 1 cc. of concentration H_2SO_4 (7).

In making the comparison with the chlorine standards, volumes of potassium dichromate and copper sulfate solutions on both sides of those given in Standard Methods (7) were used for each of the various chlorine concentrations. Comparisons were made in 100 cc. Nessler tubes having polished glass bottoms, an internal diameter of 20 mm. and a depth from the graduation mark of 300 mm. plus or minus 2 mm. The tubes were observed in a mirror camera by north light. The volumes of $CuSO_4$ and $K_2Cr_2O_7$ which best matched the recently

prepared chlorine standards are shown in the columns headed "Recheck of Standard Methods" (table 4). The columns headed "Muir and Hale Standards" (8) which are the quantities of reagents advised by those workers in preparing permanent standards, show in

TABLE 4

Permanent chlorine standards

Cl	STANDARD METHODS(5)		MUIR & HALE STANDARDS(4)			RE-CHECKED STANDARDS		
	Volume $CuSO_4$	Volume $K_2Cr_2O_7$	Volume $CuSO_4$	Volume $K_2Cr_2O_7$	Percent difference	Volume $CuSO_4$	Volume $K_2Cr_2O_7$	Percent difference
p.p.m.	*cc.*	*cc.*	*cc.*	*cc.*		*cc.*	*cc.*	
0.01	0	0.8	0.3	1.8	+125	0	0.8	0
0.02	0	2.1	0.5	3.2	+52.4	0	1.7	−20.0
0.03	0	3.2				0	2.8	−12.5
0.04	0	4.3	1.0	6.1	+42.0	0	3.9	−11.0
0.05	0.4	5.5				0.4	5.0	−9.0
0.06	0.8	6.6	1.4	8.7	+31.8	0.8	6.1	−8.0
0.07	1.2	7.5				1.2	7.2	−4.0
0.08	1.5	8.7*	1.7	11.0	+26.4	1.4	8.3	−4.6
0.09	1.7	9.0				1.4	9.4	+4.4
0.10	1.8	10.0	1.9	13.0	+30.0	1.4	10.5	+5.0
0.15			1.9	1.7		1.5	1.4	
0.20	1.9	2.0	2.0	2.1	+5.0	1.7	1.8	−10.0
0.30	1.9	3.0	2.0	3.0	0	1.8	2.8	−6.6
0.40	2.0	3.8	2.0	3.8	0	2.0	3.8	0
0.50	2.0	4.5	2.0	4.7	+4.4	2.3	4.5	0
0.60	2.0	5.1	2.0	5.5	+7.8	2.3	5.1	0
0.70	2.0	5.8	2.0	6.4	+10.0	2.4	5.8	0
0.80	2.0	6.3	2.0	7.2	+14.0	2.5	6.4	+1.6
0.90	2.0	6.7	2.0	8.1	+21.0	2.6	7.0	+4.5
1.00	2.0	7.2	2.0	9.0	+25.0	2.7	7.6	+5.5
2.00	2.0	12.0				2.8	13.6	+13.0
3.00	2.0	21.0				3.0	19.0	−10.0
Average per cent difference					+26.3			−3.0

Columns headed "percentage difference" represent deviations of volumes of $K_2Cr_2O_7$ from those given in Standard Methods.

* Obviously a misprint for 8.3 or 8.2.

nearly every case, slightly larger volumes of the potassium dichromate and in the lower chlorine ranges larger volumes of copper sulfate. The percentage differences found in the sixth and ninth columns are based on the volumes of dichromate used as compared

with those given in Standard Methods. Above 0.15 p.p.m. of chlorine the more concentrated solution of dichromate was used, i.e., 2.5 g. per liter.

Effect of order of mixing reagents on chlorine standards. Standard Methods (7) provide for the addition of 1 cc. of the reagent to 100 cc. of the solution to be tested. In order to find the effect of diluting after the addition of the ortho-tolidine on the depth of color, four portions of a solution containing 3.72 p.p.m. of chlorine having volumes of 5, 10, 15, and 20 cc., respectively, were each treated with 1 cubic centimeter of the reagent and after allowing 15 minutes for the development of color each was diluted to the 100 cc. mark with ammonia-free water. Similar solutions containing the above amounts of chloine solution were diluted to the 100 cc. mark after which the ortho-tolidine was added. In each case those having received ortho-tolidine before dilution produced the deeper tints.

Spectral photometric studies of chlorine-ortho-tolidine solutions and of copper sulfate and potassium dichromate solutions. Transmittency measurements on chlorine-ortho-tolidine solutions containing 0.2 and 0.4 p.p.m. of chlorine were made using a Kueffel and Esser color analyzer having 10 cm. tubes, one containing the chlorine solution under examination while the other contained water. Similar measurements were made on solutions of copper sulfate and of potassium dichromate separately of concentrations corresponding to those used in the color comparisons as well as mixtures of the two solutions.

The data showed that (1) the mixtures of copper sulfate and potassium dichromate solutions are not spectral matches for the chlorine-ortho-tolidine solutions, (2) in both sets of solutions there are marked absorption bands at a wave length of 580, (3) both copper sulfate and potassium dichromate solutions have high transmittencies around 620, (4) as would be expected copper sulfate increases the absorption of potassium dichromate in the red portion of the spectrum, (5) the 0.4 p.p.m. chlorine-ortho-tolidine solution should have less copper sulfate to match it in the orange-red region, and (6) the copper sulfate-potassium dichromate curves, in general, lie below the chlorine-ortho-tolidine curves which may be due to the well known tendency of the latter solutions to fade.

INFLUENCE OF THE CHLORAMINES ON THE ORTHO-TOLIDINE COLOR

When chlorine dissolves in water it also enters into reaction to form hypochlorous acid and hydrochloric acid thus:

$$Cl_2 + HOH \rightleftarrows HOCl + HCl \quad (1)$$

The hypochlorous acid (HOCl) may, in turn, react with ammonia of ammonium salts to form monochloramine:

(2) $$NH_3 + HOCl \rightarrow NH_2Cl + H_2O$$

Dicloramine may be formed thus:

(3) $$NH_3 + 2\ HOCl \rightarrow NHCl_2 + 2\ H_2O,$$

and trichloramine thus:

(4) $$NH_3 + 3\ HOCl \rightarrow NCl_3 + 3\ H_2O.$$

Reaction (2) according to Chapin (9) predominates at a pH of 8.5 while reaction (4) takes place at a pH of 4.4 or less. Between these two extremes, reactions (3) and (4) proceed simultaneously with equilibria shifting as the pH is changed toward either extreme.

TABLE 5

Comparison of the action of ortho-tolidine on chlorine and on chloramine

CHLORINE	CHLORINE AS CHLORAMINE	COLOR COMPARISONS
p.p.m.	*p.p.m.*	
0.05	0.05	Match
0.10	0.10	Match
0.20	0.20	Match
0.30	0.30	Match
0.40	0.40	Match
0.50	0.50	Match

The chloramines produce color reactions with ortho-tolidine similar to those produced by chlorine and hypochlorous acid. Equations (1) and (2) above may be combined to read:

$$Cl_2 + NH_3 \rightarrow NH_2Cl + HCl$$

in which it will be observed that 71 parts by weight of chlorine combine with 14 of nitrogen. By use of a standard solution of ammonia, containing 12 p.p.m of nitrogen, different concentrations of the monochloramine were produced by adding the requisite quantity of chlorine solution. Each solution was then treated with ortho-tolidine and the color produced was compared with that produced by the corresponding amount of chlorine alone. The results are shown in table 5.

TABLE 6

Relation of pH, time of contact of ammonia and chlorine, and time required to develop maximum o-tolidine coloration

CHLORINE	AMMONIA NITROGEN	TIME OF CONTACT BETWEEN Cl_2 AND AMMONIA	TIME AFTER ADDING O-TOLIDINE	O-TOLIDINE READING
		At pH. 8.0		
p.p.m.	*p.p.m.*	*minutes*	*minutes*	*p.p.m.*
1.0	0.2	15	15	0.7
1.0	0.2		30	0.9
1.0	0.2	-	45	1.0
1.0	0.2	30	15	0.7
1.0	0.2		30	1.0
1.0	0.2	45	15	0.8
1.0	0.2		20	1.0
1.0	0.2	60	15	0.9
1.0	0.2		20	1.0
1.0	0.2	75	15	0.9
1.0	0.2		20	1.0
		At pH 7.0		
1.0	0.2	15	15	1.0
1.0	0.2	30	12	1.0
1.0	0.2	45	8	1.0
1.0	0.2	60	5	1.0
		At pH 6.0		
1.0	0.2	15	15	1.0
1.0	0.2	30	12	1.0
1.0	0.2	45	7	1.0
1.0	0.2	60	7	1.0
		At pH 5.0		
1.0	0.2	15	12	1.0
1.0	0.2	30	10	1.0
1.0	0.2	45	8	1.0

Other combinations of ammonia with chlorine ranging from 1 p.p.m. of ammonia nitrogen and 20 p.p.m. of chlorine down to one of the former and 1.66 of the latter were made and each produced colora-

tions with ortho-tolidine which were identical with those produced by corresponding amounts of chlorine alone.

Time required for the chloramine reaction and for the ortho-tolidine reaction. Works operators have generally observed that more time is required to produce the maximum ortho-tolidine color in the presence of ammonia than in its absence. That considerable time should be allowed between the time of mixing the ammonia and the chlorine and the time of making the test together with the influence of the pH of the solution has probably not been so generally recognized. Table 6 records some tests made in which these factors were considered.

At a pH in the neighborhood of 8.0 short contact period should be followed by a long ortho-tolidine reaction time, while a longer contact time requires a shorter time for production of the maximum color which should not be less than 20 minutes in any case. As the pH is lowered, contact time and reaction time may both be shortened, but in these pH ranges ten minutes for o-tolidine reaction may be considered a safe minimum if the contact time has been 45 minutes or more.

REACTIONS OF MANGANESE COMPOUNDS, CHLORINE AND ORTHO-TOLIDINE REACTION

The interference of manganese with the ortho-tolidine test is well recognized. Buswell and Boruff (10) observed that 25 p.p.m. of manganese produces a darkening effect equal to that produced by 0.6 p.p.m. of iron. The work of Hopkins in this connection has already been cited (see "Nature of Ortho-Tolidine Reaction"). The present authors have found that manganous compounds are without ability to produce color with ortho-tolidine, hence their attention was directed to those factors, namely, oxygen, and chlorine, which tend to oxidize the element to some higher state. It will be recalled that the manganese atom has valences of 2 as in manganous compounds; of 3 as in manganic salts; of 4 as in MnO_2; of 6 as in the manganates MnO_4^{--}; and of 7 as in permanganates MnO_4^-. It would be expected, therefore, that the trivalent atom would be equivalent to one atom of chlorine, the tetravalent to two atoms, the hexavalent to four chlorine atoms, and the heptavalent to five.

In order to determine the effect of pH and time of aeration on manganous salts, studies were undertaken, the results of which are recorded in table 7. The oxidized manganese was determined by iodimetric means.

It is apparent that at pH values under 7, manganous compounds

are incompletely oxidized to the manganic state by atmospheric oxygen while at values of 7 and 8 the oxidation is practically quantitative. At a pH of 9.4 some oxidation beyond the manganic condition is obtained.

Additive effect of oxidized manganese compounds with chlorine. The results obtained by adding ortho-tolidine to solutions containing oxidized manganese and chlorine show definitely that the color obtained is an additive result of the action of the two constituents, chlorine and manganese. The quantitative data are given in table 8.

TABLE 7

Oxidation of manganous salts by atmospheric oxygen at different pH values

pH	Mn^{++} CONCENTRATION	TIME OF AERATION	VOLUME TITRATED	VOLUME N/200 $Na_2S_2O_3$ REQUIRED	WEIGHT OF OXIDIZED Mn	PER CENT OF Mn^{++} OXIDIZED TO Mn^{+++}
	p.p.m.	*hours*	*cc.*	*cc.*	*p.p.m.*	
5	1.25	2	1,000	0	0	
5	1.25	8	1,000	1.4	0.385	30.8
6	1.25	2	1,000	0	0	0
6	1.25	8	1,000	0.96	0.264	21.1
7	1.25	2	1,000	4.3	1.182	94.6
7	1.25	3	1,000	4.3	1.182	94.6
8	1.25	1	1,000	4.5	1.237	99.0
8	1.25	2	1,000	4.5	1.237	99.0
9.4	1.25	2	1,000	6.8	1.870	149.6
9.4	1.25	6	1,000	7.1	1.952	156.2

TABLE 8

The additive effect of manganic and permanganate manganese with chlorine

(Results in parts per million)

MANGANESE ADDED	CHLORINE EQUIVALENCY	CHLORINE ADDED	TOTAL CHLORINE EQUIVALENCY	O-TOLIDINE READING
0.23 as Mn^{+++}	0.15	0.15	0.30	0.30
0.31 as Mn^{+++}	0.20	0.20	0.40	0.40
0.046 as MnO_4^-	0.15	0.15	0.30	0.30
0.062 as MnO_4^-	0.20	0.20	0.40	0.40

Oxidation of manganous manganese by chlorine in absence of dissolved oxygen. Using standard solutions of manganous salt and of chlorine a series of mixtures of the two in oxygen-free water was prepared having ratios of 1, 2, 3, and 4 parts of chlorine, respectively, to one part of manganese. After adjustment of the different solutions

to various pH values they were boiled under reduced pressure in order to expel the excess chlorine (it having been proven previously that chlorine could thus be removed from solution) after which the state of oxidation of the manganese was determined by iodimetric titration.

TABLE 9

*Oxidation of manganous compounds by chlorine in absence of oxygen**

pH	MANGANOUS Mn ADDED	CHLORINE ADDED	PER CENT OXIDATION
	p.p.m.	*p.p.m.*	
4	1.25	1.25	None
4	1.25	2.50	None
5	1.25	1.25	35.6
5	1.25	2.50	55.8
5	1.25	3.75	55.8
6	1.25	1.25	35.0
6	1.25	2.50	61.5
6	1.25	3.75	63.4
7	1.25	1.25	40.4
7	1.25	2.50	72.4
7	1.25	3.75	156.0
7	1.25	5.00	203.4
8	1.25	1.25	53.6
8	1.25	2.50	87.8
8	1.25	3.75	194.2
8	1.25	5.00	194.0
9	1.25	1.25	119.5
9	1.25	2.50	175.7
9	1.25	3.75	175.7
9	1.25	5.00	193.3

* Time of contact ranged from 3 to 10 minutes.

The degree of oxidation was expressed in per cent, the complete oxidation of bivalent manganese to trivalent being counted as 100 per cent oxidation while oxidation to the tetravalent condition was counted as 200 per cent.

ESTIMATION OF MANGANESE IN WATERS

Forman (11) proposed a method for estimating manganese in waters by bubbling air or oxygen through the sample made alkaline

with NaOH or KOH, followed by acidification and the addition of ortho-tolidine, the resultant color being matched with chlorine standards. In view of the data given (tables 7 and 9) it is not surprising that this method gives inconsistent results.

Richards (12) proposed a method for estimating small amounts of manganese which uses sodium meta-periodate, $Na_2H_3IO_6$, the manganese being oxidized to permanganic acid which is read colorimetrically by comparing with permanganic acid standards similarly prepared. The authors have adapted this method to the estimation of manganese in water by the following procedure:

(a) A standard manganous solution (0.05 mg. Mn^{++} per cubic centimeter) is prepared by reducing 143.8 mg. of pure $KMnO_4$ dissolved in 100 cc. of water containing 10 cc. of 6 normal sulfuric acid with 400 mg. of sodium bisulfite after which the sulfur dioxide is boiled off and the solution, after cooling, is diluted to one liter.

(b) A 6 percent (by volume) solution of sulfuric acid is prepared by diluting the acid in the ratio of 30 cc. of C.P. conc. H_2SO_4 to 500 cc. with distilled water after which 800 mg. of sodium meta-periodate are added. (The periodate may be obtained from G. F. Smith & Company, Columbus, Ohio.) The diluted acid and periodate are heated to boiling and then placed 30 minutes in a boiling water bath. This is the 6 percent sulfuric acid solution mentioned hereafter.

(c) Preparation of permanganic acid color standards. Twenty cubic centimeters of the standard manganous solution ((a) above) are treated with 1.2 cc. of concentrated sulfuric acid after which 30 cc. of the 6 percent acid are added followed by 300 mg. of sodium meta-periodate. The solution is heated to boiling and then placed 30 minutes in a boiling water bath. After cooling it is diluted to one liter by adding 6 percent sulfuric acid. This standard contains 1 mg. of permanganate manganese per liter. By withdrawing aliquots of this solution and diluting to 100 cc. by adding 6 percent sulfuric acid, color standards ranging in value from 0.025 to 1 p.p.m. may be prepared. These standards should be stored in glass stoppered bottles which have been cleaned by the use of hot dichromate cleaning solution, rinsed with distilled water and dried. Because of the presence of the excess periodate these standards will keep indefinitely.

(d) Examination of the water. One hundred cubic centimeters of the water under examination is evaporated to a small volume in a 250 cc. Erlenmeyer flask or beaker. To insure the removal of HCl,

in case chlorides are present, it is advisable to add 3 or 4 drops of concentrated sulfuric acid before evaporating. To the concentrated liquid 50 cc. of 6 per cent sulfuric acid are added followed by 500 mg. of sodium meta-periodate. The liquid is heated to boiling and placed 30 minutes in boiling water to complete the oxidation of the manganese present to permanganic acid. After cooling, the solution is transferred to a 100 cc. Nessler tube, more 6 percent sulfuric acid being used to rinse the flask or beaker. The liquid is brought to the 100 cc. mark on the Nessler tube by adding 6 percent H_2SO_4, well mixed and compared with the manganese color standards placed in similar tubes. The comparison should be made in a mirror photometer.

ESTIMATION OF RESIDUAL CHLORINE IN THE PRESENCE OF MANGANESE

Enslow (13) proposed a method for correcting manganese errors in chlorinated waters in which a sample of the water is boiled until approximately 25 percent has evaporated after which it is cooled and made up to the original volume by adding a manganese-free water. Ortho-tolidine is then added and the "false residual chlorine" is read. This amount subtracted from the ortho-tolidine reading on the unboiled sample, it is claimed, will give the true residual chlorine. He cautions against acidification of the sample before boiling presumably lest manganous compounds act catalytically upon the manganic to reduce them.

The authors have found that waters having a pH of 8.0 to 8.4 which contain dissolved oxygen and 1.25 p.p.m. of manganous manganese will, through oxidation, develop a chlorine equivalency of from 0.40 to 0.67 p.p.m. during a boiling period of 5 to 10 minutes. Since waters so frequently contain oxygen it *is very certain* that boiling to expel chlorine would oxidize any containing manganese enough to render the method of no value.

The authors propose the following two solutions to this problem:

(1) *Correcting for oxidized manganese.* On the basis of the studies set forth in this paper the authors would propose the following method for correcting errors due to manganese in chlorinated waters when the ortho-tolidine test is applied.

(a) Determine total manganese in the raw water as proposed above using the periodate method.

(b) Determine oxidized manganese immediately ahead of the chlorinators using the ortho-tolidine method.

(c) By difference of (a) and (b) calculate the amount of manganous manganese in the water before chlorination.

(d) Measure the pH a few minutes after the water has passed the chlorinators also observe the rate of chlorination.

(e) Knowing the pH of the water and the manganous-chlorine ratio, refer to table 9 and determine the percentage of the manganese oxidized. If the percentage is over 100 add the excess as additional manganese since this will represent oxidation of the element beyond the trivalent state.

(f) Multiply the oxidized manganese found in (e) by the factor 0.645 to obtain the chlorine equivalent.

(g) Make the ortho-tolidine test on the finished water and subtract the calculated chlorine equivalency of the oxidized manganese found in (f) to get the residual chlorine.

(2) *Reduction of oxidized manganese by hydrogen peroxide.* That hydrogen peroxide in acid solution is capable of reducing the permanganate ion and manganese dioxide to the manganous state has long been known to chemists.

$$2\ MnO^-_4 + 5\ H_2O_2 + 6\ H^+ \rightarrow 2\ Mn^{++} + 8\ H_2O + 5\ O_2$$
$$MnO_2 + H_2O_2 + 2\ H^+ \rightarrow Mn^{++} + 2\ H_2O + O_2$$

It occurred to the authors that use might be made of these and similar reactions in reducing manganese compounds oxidized above the bivalent condition to the manganous state, thus clearing the way for the application of the ortho-tolidine test to manganese containing waters. The applicability of reduction by means of hydrogen peroxide was tested as follows:

1. Preparation of hydrogen peroxide solution. A 3 percent solution of hydrogen peroxide was diluted to a 0.02 percent solution (approximate). The resulting solution was checked by iodimetric titration.

2. Action of 0.02 percent hydrogen peroxide on ortho-tolidine. Five cubic centimeters of such a solution treated with 0.1 percent orthotolidine solution in 10 percent HCl produced no coloration when viewed lengthwise through a 100 cc. Nessler tube.

3. Action of a 0.02 percent hydrogen peroxide on a manganic solution. Water containing 8 or more p.p.m. of dissolved oxygen and having a pH of 9 was treated with a standard manganous solution (0.05 mg. per cubic centimeter) so as to make a solution containing 1.25 p.p.m. This solution was allowed to stand over night

after which 500 cc. of it was acidified by adding 10 drops of 6 normal H_2SO_4. One hundred cubic centimeters of the solution were withdrawn and the oxidized manganese determined iodimetrically. Then 10 drops of 0.02 percent H_2O_2 solution were added to the remaining 400 cc. of solution and at 10 minute intervals 100 cc. portions were analyzed (see table 10).

TABLE 10

Reduction of manganic manganese by a 0.02 percent hydrogen peroxide solution

TIME INTERVAL	VOLUME TITRATED	VOLUME OF N/200 $Na_2S_2O_3$ USED	Mn^{+++}
	cc.	*cc.*	*p.p.m.*
Start	100	0.43	1.18
After 10 minutes	100	0.40	1.09
After 20 minutes	100	0.22	0.60
After 30 minutes	100	0.14	0.38
After 40 minutes	100	0.00	None

TABLE 11

Reduction of manganic compounds by 0.02 percent hydrogen peroxide in the presence of chlorine

(Results in parts per million)

CHLORINE ADDED	Mn^{+++} ADDED	Cl EQUIVALENCY OF Mn	TOTAL CHLORINE EQUIVALENCY	TIME INTERVAL	CHLORINE EQUIVALENCY FOUND
				minutes	
0.75	0.74	0.48	1.23	Start	1.14
0.75	0.74	0.48	1.23	10	0.92
0.75	0.74	0.48	1.23	20	0.78
0.75	0.74	0.48	1.23	30	0.71
0.75	0.74	0.48	1.23	40	0.71
0.75	0.74	0.48	1.23	60	0.71
0.75	0.74	0.48	1.23	90	0.71

4. Action of 0.02 percent hydrogen peroxide on chlorine solution. The procedure was similar to that used in case of manganese and the analysis of 100 cc. portions of a 500 cc. solution containing 5 p.p.m. of chlorine and 10 drops of 0.02 percent solution showed no decrease in the chlorine over a 40 minute period.

5. Action of 0.02 percent hydrogen peroxide solution on manganic manganese and chlorine.

A solution was prepared containing 0.75 p.p.m. of chlorine and 0.74 p.p.m. of manganic manganese. The latter had a chlorine equivalency of 0.48 p.p.m. making the total chlorine equivalency equal to 1.23 p.p.m. This mixture, having a volume of 800 cc., received 1 cc. of 0.02 percent hydrogen peroxide after which iodimetric titrations on 100 cc. portions were made at 10 minute intervals. From table 11 it is apparent that the hydrogen peroxide reduced the manganic manganese in 20 to 30 minutes leaving the chlorine largely unaltered in concentration (0.71 p.p.m. as compared with the 0.75 p.p.m. added).

Procedure for estimating residual chlorine in the presence of manganese. The actual available chlorine may be determined as follows:

1. Make the regular ortho-tolidine test on the chlorinated sample of water using a 100 cc. tube. Read the apparent chlorine (chlorine plus manganic salts).

2. Place 100 cc. of the sample in a second tube, add 2 or 3 drops of 6 normal H_2SO_4 and 10 or 12 drops of a 0.02 percent hydrogen peroxide solution, mix thoroughly and allow to stand 40 minutes. Add 1 cc. of the ortho-tolidine solution and after 5 minutes read the tube. This gives the true residual chlorine in the water.

3. If desired, the quantity of manganic manganese can be estimated by subtracting the reading obtained in 2 from that obtained in 1. Multiplying this figure by 1.55 gives p.p.m. of manganic manganese. It should be observed that the last value does not necessarily represent total manganese but only that which is oxidized beyond the manganous state. The authors do not recommend the use of ortho-tolidine in the determination of manganese. They have found the periodate method previously described more satisfactory.

Care should be exercised to see that the 0.02 percent hydrogen peroxide solution does not decompose. A new solution should be prepared each week and a fresh 3 percent solution should be obtained monthly.

SUMMARY

The ortho-tolidine color reaction may be produced in the absence of chlorine and chlorides by the use of an equivalent quantity of a manganic compound thus proving quantivatively that the color formation is an oxidation reaction rather than one of chlorination.

The chlorine standards as given in the Sixth Edition of Standard Methods have been checked and found to be substantially correct.

The chloramines are without final effect on the ortho-tolidine reaction as compared with that produced by equivalent quantities of chlorine, but the former require longer time for full development of color and in the higher pH ranges the ammonia and chlorine should be allowed a sufficient contact time before the ortho-tolidine test is made. From 10 to 20 minutes are necessary for the development of color.

Manganous compounds are without ability to produce color reactions with ortho-tolidine while manganic and permanganate produce colorations identical with those of chemically equivalent quantities of chlorine.

Atmospheric oxygen may oxidize manganous compounds in alkaline solution as high as the manganic stage.

Chlorine in the absence of oxygen may oxidize manganous salts in increasing degrees with increasing pH until the tetravalent condition of manganese has been reached. There seems to be no oxidation of manganous compounds by chlorine below a pH of 4.

Manganic and permanganate manganese in the presence of chlorine produce additive effects on ortho-tolidine.

A modification of the Richards method for estimation of manganese in waters is offered in which sodium meta-periodate is employed and permanent color standards of permanganic acid are used for comparison.

A method for estimating residual chlorine in the presence of manganese is suggested, account being taken of total and oxidized manganese, the chlorination rate and pH of the solution.

A second method for chlorine in the presence of manganese is offered in which a 0.02 percent solution of hydrogen peroxide is used to reduce all manganese to the bivalent condition after which the ortho-tolidine reaction may be employed.

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DISCUSSION

L. H. Enslow:[1] The authors suggest in their paper one procedure for determining true residual chlorine in the presence of oxidized manganese which is complicated and impractical, but a second is recommended that is simple and practical. What of its accuracy and dependability? Only the test of its application under varied conditions can determine that. Preliminary tests under actual operating conditions indicate that, if their procedure be carried out with hydrogen peroxide of dependable strength and if the procedure be followed with reasonable care, the resultant true residual chlorine as distinct from the apparent residual created by the presence of oxidized manganese, seems to be for all practical purposes that secured by the boiling-out procedure (13) applied to the same samples. This in spite of the fact that the latter method is condemned by the authors as being of doubtful value.

The boiling-out test referred to was proposed as a very simple means of removing the true chlorine and leaving the oxidized manganese undisturbed. Then the orthotolidin test applied to the boiled sample discloses the "blank," i.e., the fictitious residual chlorine value caused by reaction of oxidized manganese on orthotolidin, which must be deduced from the total (apparent) residual found in an unheated sample. In this way the actual chlorine present is indicated from the difference in the two readings.

In as much as Adams and Buswell have evaluated—or rather have devaluated—the boiling out test on what would appear to be principally theoretical grounds, it becomes necessary to reply in some measure to their objections.

Until these investigators stated that unoxidized manganese would become oxidized during boiling of a water sample, the chief complaint against the method was that in at least one instance there has been some reduction during boiling of what was apparently oxidized manganese in *unchlorinated* waters. In fact it has been observed in prac-

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tice that some raw (unchlorinated) waters giving a positive test for chlorine with orthotolidin does lose that power somewhat as the result of boiling. It has been on that account that the method proposed by Forman is used in routine testing of the Wanaque N. J. water supply to oxidize all manganese present. The color obtained with the orthotolidin test applied to the oxidized sample is thereafter deduced from the apparent cylorine content of the treated water. The "blank" so determined is a bit too high, but the error in determination of the actual chlorine content is on the safe side. In the routine control of chlorine dosage it has the value of being safe and if proven practicability even though its inaccuracy may not meet the approval of men of scientific per specacity or that of scrutinizing analysts.

Concerning the boiling-out test. Considering the boiling-out test, its use in practice does not seem to condemn it, notwithstanding its critics. It has never been advocated as a scientific or a truly accurate method of arriving at the content of oxidized manganese as distinguished from true chlorine content. It however serves as a method which is highly useful, and aside from slight inaccuracy, as a method that is applicable in kitchen or laboratory—in the hands of the green operator or the seasoned chemist. It requires but the ability to boil water and then make it up to original volume and thereafter the application of the routine orthotolidin test. It requires but a single reagent that does not deteriorate for require exactness in compounding or manipulation.

The rise in pH value of water which results from boiling, and the supposition that there is a resulting odixation of some of the manganese by the dissolved oxygen present, leads Adams and Buswell to contend that the test has no value. Theoretically they may be correct, but if they offer this condemnation backed by actual experience it fails to check with practice. Boiling raises the pH of certain water samples from 7.1 originally to 9.2 but *without producing oxidation* of even a *trace* of the manganous manganese present. The same water after chlorination and then boiling, gives a residual chlorine "blank" (due to manganese) which is equivalent to 0.5 p.p.m. chlorine and an actual residual chlorine content of but 0.1 p.p.m. If after boiling away 33 cc. of an unchlorinated 100 cc. sample of the same water it is then made up to original volume with an oxygen bearing water the pH value of the diluted sample will be 8.2 and sufficient manganese is oxidized to give a color with orthotolidin equal to that produced by

0.04 p.p.m. chlorine. The error due to the boiling test had therefore been something less than 10 per cent of the "blank" obtained following complete oxidation of all manganese present.

If the water sample already has a pH value of 8.4 or thereabouts and manganese be present it is true that the oxygen in the water will oxidize some if not all of the manganous to manganic compounds. Heating will naturally speed up the reaction but under natural circumstances one rarely finds waters of such high pH values containing manganous manganese. When the pH value is artificially raised then the oxidation of manganese will occur without the aid of heating and if chlorine application has been sufficient, it will be completely oxidized. If the boiling test produces a higher residual chlorine test than that obtained on the unboiled sample (the latter being a part of the complete test) it becomes evident that insufficient chlorine has been applied to the water, or else none at all has been applied as was the case in the test referred to by Adams and Buswell. If the test had been applied to a chlorinated sample of the water as stimulated in the procedure, the results would have been of a different order and the "blank" being higher than the apparent chlorine value found in routine testing practice would have indicated a minus value for true chlorine residual.

If the theoretical objections to the boiling test were supported in practice the complaint would be against its erring on the safe side in chlorination control. Simplification in control of process is of more consequence than the quibbling for accuracy when it comes to water chlorinating and prior to the appearance of the boiling-out method there was no really practical test available for readily differentiating between manganese and residual chlorine.

In summation: (1) The method suggested by Adams and Buswell in which the manganese is reduced by the simple expedient of applying a solution of hydrogen peroxide, without attacking the true residual chlorine, is worthy of consideration as a feasible and practical procedure. The peroxide solution must be correct and the contact period not too short nor too great.

(2) Use of the Forman method to determine the actual plus the *potential* fictitious residual chlorine value is an ultra safe means of controlling chlorine dosage by maintaining a minimum residual value.

(3) Use of the boiling out method to determine the deductable "blank," created by oxidized manganese, remains a practical, though an admittedly unrefined, scheme which will prove highly useful for

routine chlorination control in the hands of unskilled men as well as others. It will probably never attain the distinction of being an approved procedure for inclusion in "Standard Methods" of the A. P. H. A., but it stands fair to find a place in the scheme of things—notwithstanding.

It does seem that when a water sample contains ammonia and is alkaline, to the extent of having a pH value above 8.2 to start with, it is advisable to almost neutralize the alkalinity before boiling, taking care not to actually acidify lest manganese be reduced. Boiling off 25 to 33 per cent of the original sample seems to be sample for chlorine removal. When no monochloramine has been produced neutralization with acid is not needed. Where considered necessary to avoid oxidation of additional excessive manganese, when diluting samples to original volume, use recently boiled water.

THE ROCKFORD WATER SUPPLY

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The early history of the Rockford water supply and its "cut and try" method of development is fairly representative of the history of the development of the earlier water supplies in the Middle-West. In the early seventies few cities of the Middle-West were provided with public water supplies. There were therefore few men with any considerable knowledge of water works or water supplies, and there was perhaps no place where a city could go for competent advice on this subject. When the City of Rockford, therefore, decided that a public water supply was necessary, it was obliged to rely on the good sense of the city officials with such advice as they were able to obtain from those manufacturers and agents who were furnishing machinery, pipe, valves, hydrants or other equipment that was necessary to be used in such developments.

From the "state of the art" it was hardly to be expected that such developments could be made at that time and under those conditions without more or less serious mistakes, and any discussion of such early endeavors should take into account the handicaps under which such works originated and developed.

Early in the seventies the City of Rockford, with a population at that time of about 12,000, decided that a municipal water supply was desirable.

The original waterworks was constructed during the years 1875–76 while the writer was a boy in the grammar school in South Rockford. The works were designed by Birdsall Holly who was connected with the Holly Manufacturing Company of Lockport, New York, which company constructed the original Rockford Water Works under contract. Holly was, I believe, the first to design a pumping engine capable of varying its amount of discharge in such manner that the pressure in the mains would remain practically constant. This made possible direct pumping into a system of mains without the intervention of a reservoir or stand pipe to regulate the pressure on the system.

In this manner an economy was effected in first cost and sometimes, although perhaps not frequently, in operation expense as well. For many years the Holly system of direct pumping was a factor of some importance in water works design.

The original distribution system of Rockford consisted of about 21 miles of mains, almost 40 percent of which was of pipe 4 inches and less in diameter, with 166 fire hydrants. The pumping equipment first installed consisted of a Holly quadruplex steam pump of two million gallon rated capacity per day. As a reserve there was installed a steam engine driving two Holly rotary pumps, each having a capacity of one million gallons per day.

The site chosen for the pumping station was on the west side of the Rock River three blocks north of State Street. This location was selected on account of certain springs which had long been known at that point and had been used as a source of domestic water supply by the people in that vicinity. These springs came from a gravel deposit that underlay the residential portion of the city between the river and Kents Creek. These springs were developed as a source of supply by laying a series of tile somewhat below the ground water surface, these tile radiating from a central basin which was called an infiltration well. This basin was built of brick, and the tile within the basin were covered with coke, gravel and stone through which material the water percolated upward and flowed to a pumping pit from which the water was finally drawn by the pumping machinery and forced into the system of mains. The pumping pit was founded on the gravel some distance below the ground water surface, but otherwise was bottomless and from this gravel furnished an additional water supply. An inlet pipe closed by a gate valve connected the upper portion of the filter chamber with the river for emergency purposes. The quantity of flow of the original springs was unknown, nor is there any record of the capacity of the water supply developed by the filter well above described. The site of the original pumping station is on slack water about one-half mile above the water power dam which was built across the Rock River on the old rock ford which gives the city its name and which is located just south of the center of the city.

In discussing this original supply it is desirable to remember that the sanitary relations of domestic water supply were not then understood nor was any knowledge of water borne diseases generally available. The river water in the seventies was clear and free from the

pollution which later developed with the settlement of the country and the installation of public and private sewers.

The extra expense in hauling coal to the station due to the distance from the railroads was probably not appreciated when the station was located. It is probable, however, that even had this extra expense been realized, the springs as a source of supply would have been considered of sufficient importance to warrant the selection of this location.

The original plant was constructed under the immediate supervision of a Committee of the city council and was in charge of succeeding committees on fire and water until 1883 when the office of Superintendent of Water Works was first created.

It is understood that the filter well was inadequate from the first, and that water from the river had to be relied upon whenever a considerable demand for water occurred. In 1881, the Fire and Water Committee reported that the "filter well" was insufficient to supply the demand for water, and recommended the construction of a large filter well or of a well of sufficient capacity to meet the demands. This Committee was authorized by the city council to build a new well and did construct, south of the pumping station, a well 50 feet in diameter and 38 feet in depth with a center well 12 feet in diameter to an additional depth of 20 feet or more. This well drew its supply from the extensive sand and gravel deposits from the upper part of which the so-called filter well obtained its supply. The new well was of greater depth and had a corresponding increased capacity, and was reported by the Committee in 1882 to furnish an adequate supply of satisfactory water.

As with most communities, the original domestic water supply of Rockford was obtained from wells reaching the ground water usually in underlying gravel, and, while perhaps occasionally polluted by vaults and surface waters had been reasonably satisfactory for domestic purposes. With the advent of the water works system, the advantage of water under pressure in the household was soon recognized, plumbing fixtures and interior closets were installed, and the wells which formerly had served as supplies were abandoned. With the advent of household plumbing fixtures, some method for the disposal of the waste water from the house became necessary. As sewers were not available, many of the wells were turned into cess pools into which the domestic wastes were poured, thus inadvertently adding to the pollution of the supply, already somewhat polluted by vaults and surface seepage.

In 1885, analyses of the well water showed that it was highly polluted and much worse than the river water, so the use of the well and the so-called filter well was discontinued and river water was admitted to the pumping pit and used as the source of supply.

It should be noted that ground water still flowed into the pumping pit as this water, held back by the water in the river, was of necessity higher than the water which flowed into the pit from the river; hence the polluted groundwater, while reduced in quantity by the river water was still a part of the supply, although this fact was not known by the public or recognized by the city officials.

GEOLOGICAL FEATURES

In 1885, the possibilities of artesian water were first discussed, and the late Dr. T. C. Chamberlain, then Professor of Geology at Beloit College and who was in charge of Glacial Geology for the U. S. Geological Survey and had also been State Geologist of Wisconsin, was consulted concerning this matter. The writer who had been engaged in geological work with the U. S. Geological Survey under the direction of Dr. Chamberlain, prepared a map and section showing the geology of Wisconsin and Northern Illinois, and the surface location of the outcrop of the Potsdam and St. Peters Sandstones through Wisconsin, with their probable position relative to the underlying strata in Northern Illinois. With this map and section Dr. Chamberlain explained the geological conditions to the Mayor and City Council and expressed the opinion that a flowing artesian well would be possible in Rockford at the site of the water works station. The writer's introduction to the Mayor and City Council of Rockford through Dr. Chamberlain resulted in his appointment as the first City Engineer and in a more intimate knowledge of the city and its water supply.

To understand the geological conditions that control the waters available for possible supplies for the City of Rockford, it is necessary to understand that in early geological times a great mountain range of granite and allied crystalline rock extended from Labrador southwesterly through Canada, into the United States, and appeared in northern Wisconsin and Minnesota with high peaks which are but poorly represented by the relief of the country today. The same rocks or rocks similar thereto extended far below the sea level in either direction from the great crystalline centers that appeared above the primeval sea. These are the base rocks on which were deposited below the sea level the stratified deposits which were

derived from the outcrop of the same deposits where they appeared above the sea. These deposits exposed to climatic influences were denuded by the same disintegrating agencies which are today tearing down and carrying to the sea the surface rocks and mantle deposits of our farms and country. From these disintegrated, exposed crystalline rock surfaces were laid down the stratified rocks of the upper Mississippi valley as they are known today. These stratified deposits slope away westerly, southerly and easterly from the mountain centers of their origin and vary in character with the time and conditions under which they were laid down. They consist of sandstones, limestones and shales as we now know them. If at the present time we should start from central Illinois and travel northward to the site of the ancient mountains in northern Wisconsin, we would start from an outcrop of the coal measures and pass in succession over outcrops of the Niagara limestone, the Hudson River shales, the Trenton and Galena limestones, the St. Peter sandstone, the magnesium limestone, the Potsdam deposits, and finally reach the crystalline rocks from which all of these later deposits have been formed. These stratified deposits had been laid down like the leaves of a book, one deposit above the other, sloping away from the crystalline nucleus.

In the course of time the mountains were greatly reduced in altitude, the sea slowly receded, and the surface appeared and was subject to the same disintegrating and denuding agencies which originally were the direct cause of their existence. The first deposit lying on the ancient crystalline bed is known as the Potsdam or the St. Croix deposit; it underlies much of the upper Mississippi valley and consists largely of sandstones interbedded with shales and limestone. These strata are the great sources of underground water supply in Wisconsin, Minnesota, Iowa, and Illinois. Overlying this deposit is a bed of magnesium limestone which while cracked and fissured in places is a large element in confining the waters of the Potsdam and in creating the artesian conditions which are quite common in wells from that source.

Above the magnesium limestone is a fairly uniform bed of almost pure quartz sand grains, known as the St. Peter sandstone. This in turn is covered by the Trenton and Galena limestone which is the surface rock found in the local quarries around the City of Rockford. and in the foundation of the dam at the old ford. The Trenton and Galena limestone were in turn covered first by the Hudson River shale and above this was deposited the Niagara limestone. These

deposits while not found locally at present probably at one time covered the site of Rockford, with hundreds of feet of indurated rocks that have since been removed by denuding agencies. In fact, the Niagara limestone which is found on top of Blue Mounds in Southern Wisconsin and on the same parallel in eastern Wisconsin and in eastern Iowa, undoubtedly extended over this whole section of the country to a great depth.

Since the emergence of the strata from the seas in which they were deposited, the agencies of denudation have worked for thousands of years until there remained over the upper Mississippi valley and adjoining territory a rugged country with high hills and deep valleys covered with vegetation and inhabited by prehistoric animals—long since extinct—the presence of which is known only by the remains of their skeletons which have been preserved in part and occasionally completely in the swamps, marshed, and drift of the present day.

Following the development of the rugged country described above and for reasons which can only be surmised there followed an age colder than the present time in which tremendous snowfalls in north central Canada, unmelted in the short summer of that age, gathered and consolidated into ice which was pressed southward by the super incumbent masses and gradually flowed from Canada into what is now known as the United States, deeply covering the upper Mississippi valley and, with slight exceptions, the entire northern United States from Wyoming and Montana eastward over the Great Lake region, including New York and the New England States. These glaciers in their passage brought from the hills of Canada and the northern United States, boulders, gravels, sands and clays which filled the ancient valleys frequently to a depth of 200 feet or more, covered most of Southern Wisconsin and northern Illinois with a deep covering of ice which forced its way to the extreme southern portion of Illinois where a line of morainic hills just north of Cairo marked the limits of its travels. The tops of the hills were ground down and added to the valley fill. The drainage systems were blocked, and in many cases almost entirely rearranged. On the recession of the glaciers, the water from the melting ice created new drainage channels which in many cases occupied the upper part of the old valleys but generally created new valleys which in many cases differ largely from the valleys of the preglacial streams.

The Mississippi River, while it occupies in general the upper part of the same valley which the old river occupied, has been forced from

its bed in many places, and at the present time through its upper valley flows 200 feet or more above its ancient bed. The smaller rivers were changed to even a greater extent, raised by the valley fills, and forced by the ice through the saddles between ancient hills when outlets existed at higher level. The present streams follow, though only to a very limited extent, the drainage channels in which the preglacial streams flowed; and in general wherever a river in the upper Mississippi valley flows over a rock bed it is a clear indication that the stream is out of the preglacial channel at that particular point.

THE ROCK RIVER

The present Rock River lies directly above its ancient valley at Lake Koshkonong in southern Wisconsin, but from that point flows above the west side of the preglacial valley through Janesville and Beloit, and at Rockford it turns to the southwest over a saddle in the ancient hills and occupies an entirely new bed from Rockford to its junction with the Mississippi River below Rock Island. The old river through Rockford flowed almost due south from its original channel which lies east of its present location, and probably was a tributary to the preglacial Illinois River. The elevation of the old river was some 200 feet below the present river, and its ancient valley was filled with clays, sands, and gravels to a height not less than the height of the ground on which the business part of the city has been built. Through that terraine the modern Rock River has excavated its present bed. The sand and gravel fill of the ancient valley offer opportunity for a supply of water which however is subject to the surface pollutions as its waters come most largely from the local rainfalls in the Rock River valley and carry into the ground water the surface and subsurface pollution of the city and farms. The possible surface supplies at Rockford, consisting of the Rock River itself and the waters of Kents and Keith Creeks are quite obvious. Limited supplies of water can also be obtained from the cracked and fissured limestone rock whenever accessible. This water is received from both the local rainfall and possibly from the ground waters of the adjoining sand and gravel deposits. At a greater depth are found the deposits of the St. Peter sandstone into which the preglacial Rock River had carried a portion of its valley at and above Rockford. Still deeper—some 380 feet below the surface—are found the Potsdam deposits which are the main source of water supply which is being used at Rockford at the present time.

In Wisconsin the Potsdam deposits occupied a surface area of about 14,000 square miles in an irregular crescent area around the ancient crystalline mountain base and are, in the main, covered by glacial drift. The Potsdam deposits receives from their outcrop in this area by direct rainfall, from streams flowing over their outcrop, and by seepage through the overlying drift deposit in others, those waters which they transmit radially from the crystalline nucleus in the central north part of Wisconsin, southerly, southeasterly and southwesterly to the portions lying below the surface under the adjoining states. The St. Peter sandstone, separated from the Potsdam by the lower magnesium limestones, outcrop in a comparatively narrow belt roughly parallel to the outer outcrop of the more ancient potsdam rocks.

The old valleys contain many extensive beds of sand and gravel, very irregularly laid down by the erratic glacial action and by the floods that were discharged from the receding glaciers as they melted and retreated with the changing climate of a later age. Roughly speaking, these sandstones of the indurated formations, and the sands and the gravels of the glacial epoch, constitute the main source of underground supply for the cities, towns, villages, and homes in the upper Mississippi valley. Even the hardier limestone rocks and, to some extent, the crystalline rocks of the earlier epoch are cracked and fissured and yield in places sufficient water for domestic purposes, and in some cases even sufficient for the supplies for small towns and villages.

On the advice of Dr. Chamberlain that artesian water could probably be obtained at the site of the old pumping station, the City Council decided to drill an experimental well.

SOURCES OF SUPPLY

The first well was sunk in 1885. It penetrated the St. Peter's sandstone at a depth of from 192 to 280 feet below the surface, and passed into the Potsdam sandstone at 385 feet, reaching a total depth of 1530 feet. The water rose in a closed pipe about 16 feet above the ground surface at the pumping station. Two additional wells were drilled in 1886, one to a depth of 1320 feet, while the third well was carried to a depth of 1998 feet in the hope that they would strike a coarser and more previous sandstone and thereby greatly increase the flow of water. In this, however, the community was disappointed.

Two additional wells were drilled in 1887 and 1888, respectively.

The water from these wells was allowed to flow through a conduit into the pumping pit, but was found to be inadequate for anything but the ordinary domestic supply and would have been insufficient even for this purpose except for the extra amount of water received through the gravel bottom of the pumping pit from the ground water which had been condemned in 1885. At times of heavy demand during sprinkling hours, and during fires, the river supply was still an essential feature of the system.

In 1890, a contract was made for a six million gallon capacity horizontal Gaskill pumping engine which was duly installed.

In 1891, the public demand for an adequate supply of satisfactory water became so imperative that Mayor Starr advised and, with the consent of the City Council, appointed a commission of engineers to report on this subject. This commission consisted of Mr. J. T. Fanning of Minneapolis, Mr. D. C. Dunlap, then City Engineer of Rockford, and the writer who had served as City Engineer of Rockford from 1885 to 1888. This commission measured the flow of the artesian wells and found it to be only about 1,100,000 gallons per day. At this time the reports showed that the amount of water pumped was frequently more than three times this quantity; consequently, two-thirds of the water supply of the city was drawn from the polluted ground water which had previously been condemned.

An additional supply from the St. Peter's sandstone was recommended as a first attempt. The city proceeded to drill four wells into the St. Peter's sandstone and equipped them with steam-actuated deep well pumps.

In the meantime, the late Mr. C. C. Stowell, then City Engineer and for many years also the Superintendent of Water Works, constructed a concrete reservoir near the old pumping station into which the discharge of the new wells was connected, and from which the city drew its supply. The pumps were direct-connected with the conduit from the Potsdam wells, thus cutting off the polluted ground water which was necessarily mixed with artesian water whenever the gravel bottom pumping pit was used. The water from the Potsdam wells was also pumped into the reservoir whenever the flow of these wells was greater than the immediate demand for water. By this means the reservoir was filled during the hours of minimum pumping and was available as a source of supply when the demand was greater than the artesian wells could furnish. In 1895 the supply from the above arrangement became inadequate and air lift pumps were in-

stalled to pump the St. Peter wells and also to some extent the Potsdam wells. For heavy fire service and possibly for other extensive demands, the main reliance was still the water from the river.

In 1896, the writer who had been a member of the engineering commission of 1891 and was engaged in the business of contracting, undertook to construct a shaft and tunnel system somewhat along the lines suggested in the second plan by this commission but on the basis of his own design. The idea which underlay the plan was to pump the wells from a point about 90 to 100 feet below the surface, thus greatly relieving the resistance and increasing the flow of the wells. The entire supply was then passed into a water-tight pumping pit by low lift pumps from a central shaft connected to the various wells.

It is a matter of interest that centrifugal pumps placed in a shaft about 80 feet below the surface and driven by a rope drive from a vertical engine located in an extension of the pumping station was used for this purpose. It is worthy of note that at that time no Eastern manufacturer would attempt the construction of such high-lift centrifugal pumps and that the writer was forced to go to the Pacific Coast to secure the plant which was built and installed by the Byron-Jackson Machine Works. This plant is believed to be the first high lift centrifugal pumping plant installed in the United States east of the Rocky Mountains. After many vicissitudes, this plant was completed in 1898 and the quantity secured, shown by a 24-hour test made by the city in that year, was 6,800,000 gallons per day. For the next thirteen years this supply was adequate for the needs of the city, and no river water was used for emergency needs, fire service or otherwise, although the reservoir was still kept filled as a reserve for extraordinary demands.

In 1906, an addition was constructed to the pump station, and a ten-million gallon Snow cross-compound pumping engine was installed. In the meantime, the population of Rockford was rapidly increasing, and the continuous pumping of the wells had reduced the static head of the underground waters, and consequently reduced the quantity of water available from the wells.

During the year 1909, the supply became insufficient at times of maximum pumping, and a further addition to the water supply of the city became imperative. In August of 1910, an engineering commission, consisting of John W. Alvord, Dabney H. Maury, and the writer, was appointed by Mayor Jardine to advise the city as to a

method of increasing the water supply, improving the distribution system, and other necessary modifications and improvements in the water works system. This Commission reported on eight different projects.

One plan suggested by the Commission as a temporary expedient until a more complete development could be constructed, involved the sinking of independent wells at various points in the city and pumping them directly into the water mains. This plan appealed to the City Council, and two new wells and pumping units were established: one in the southeastern part of the city, and the second on the west side of the river and near the north limits of the city on Auburn Street. This system had been recommended by the Commission only as a temporary expedient, but the units installed served their purpose and tided over the city water supply for the next ten years.

In 1919, the necessity for some further modification in the plans for water supply extension became pressing. In that year the writer was again asked to report further on the subject of water supply extension, and advised the adoption of the plan recommended by the 1910 Water Commission. This involved a new shaft and tunnel system to be built on the Galena Rock outcrop near the Chicago and Northwestern Railroad near South Street and Kents Creek.

The difficulties encountered in the construction of the original shaft and tunnel system had been so great that the Council was greatly opposed to this plan, and in 1920 the writer recommended as an alternative the construction of a new plant near the Northwestern Railroad at the corner of Avon and Cedar Streets, and four new deep wells in which either deep well centrifugal or air lift pumps were to be installed to raise water from wells into a new reservoir.

It should here be noted that the original air lift pumping plants installed by the city about 1895 had proved highly inefficient and very expensive in operation. During subsequent years, the air lift system had been greatly improved, and such a system had been installed by Mead and Seastone for the new water supply of the city of Madison about 1915. That installation had proved highly satisfactory and reasonably economical, and was suggested by the writer as a compromise method of securing a more adequate water supply for the City of Rockford. The location on the north side of Cedar Street was purchased by the city for this purpose, and a reinforced concrete reservoir of a capacity of five million gallons was built on the lot east of Avon Street, while the pumping station was built west

of Avon Street and on property accessible by side track from the railroad. In this plant were installed a new 15,000,000 gallon Snow cross-compound pumping engine, a new compressor of a capacity of 2500 cubic feet of free air per minute, and three boilers each of 300 horse power to be operated at 160 pounds steam pressure, and the necessary auxiliaries. Room was left in the pumping station for the installation of the 10,000,000 gallon cross-compound Snow pumping engine, which later was moved from the old station, and for an additional air compressor. The boiler room was built of sufficient size for a considerable addition to the steam plant, and space is available for an extension of the engine room by enlarging the building toward Avon Street.

The writer has not been in touch with the Rockford Water Works since 1924, and the present modifications of the last works above described must be obtained from the present water works officials of the city.

(Presented before the Illinois Section meeting, April 19, 1933.)

REPORT OF THE SECRETARY FOR 1931 AND 1932

The fiscal year of our Association ends with the last day of December of each year. A comparison in detail of incomes and expenditures for the years 1930, 1931, and 1932 showed excess of receipts over expenses in 1930 of approximately $3,400.00, in 1931 a little over $5,000.00, and in 1932 of $1,774.06.

For 1932, as was to be expected, the story was not quite so happy, although we kept well within our reduced budget, with the margin of receipts over expenditures still on the right side of the ledger.

While we received during the year 1931 some 226 new members, we lost through death and resignation (including those dropped for non-payment of dues) 340 members, and the decrease in revenue from initiation fees and dues amounted to a little more than $2500.00 from that received in 1930.

The increased receipts, however, from our Journal advertisers in 1931 more than made up for this loss.

The budget for 1932 was reviewed carefully and pared down by your Board of Directors. It amounts to $69,750.00, a reduction of a little more than $5000.00 from the 1931 budget approved at Pittsburgh. This budget, tentatively adopted by the Board at its January, 1932, meeting, was, for the information of the general membership, published somewhat in detail in the Journal Bulletin for February and as no comments had been received it was assumed that there were no serious objections to it.

Our gross income for the year 1932 fell off nearly $12,000.00 from the year 1931. Some $2,000.00 of this was due to the decreased registration fees received at the Memphis Convention and, of course, this was offset by the decreased expense of the Convention, especially in the banquet item. There was about $4500.00 loss in dues and initiation fees and about $5500.00 in advertising. The close of the year 1932, however, found the Association in good financial condition, the inventory showing total assets representing a surplus of nearly $38,000.00, consisting of permanent investments to the total of $30,000.00, accounts receivable, cash on hand and temporary investments, $6100.00, and office equipment, etc., with depreciation figured,

about $1800.00. These are all approximate figures. The formal report accompanying this statement gives the exact figures and the various items in detail of the inventory, financial and membership accounting. There was a loss from the Association of 327 members during the year 1932, (283 Active, 5 Corporate, 38 Associate, 1 Honorary), representing 12 percent of our membership, which, while deplorable, compares very favorably, I believe, with similar organizations.

On January 1, 1933, there were in the Association a total of 2390 members, classified as Active, 1996; Corporate, 207; Associate, 171; and Honorary, 16.

The eighteen Sections of the Association in 1932 were all, and still are, functioning in sound condition, and during the year held all the regular scheduled Section meetings, with good attendance and excellent programs. This spring one or two of the usual Section meetings have been cancelled, or postponed, because of the sudden and unprecedented nation wide bank closing, which occurred just at the wrong time. On the other hand, one or two of the recent Section meetings have registered a larger attendance than ever before. This is, we believe, a definite sign of better times or at least of a more cheerful feeling. A further indication that the downward depression curve is flattening out or is rising, is shown by the fact that for the first five months of this year, 1933, our membership list gives a net gain of 25 over the figures of the corresponding months of last year. The loss in Journal advertising does not, as yet, show signs of coming back, but we are optimistic enough to believe that at least we will now hold those advertisers we still have and that, as the general plan for Public Works construction gets under way, we shall slowly regain most of our old advertisers who felt obliged to cancel or reduce their business with us, and very probably we shall obtain new customers.

Respectfully submitted,

B. C. LITTLE, *Secretary.*

Statement of financial condition

	YEAR ENDING December 31, 1931	YEAR ENDING December 31, 1932
Assets:		
Cash on Hand	$2,884.14	$391.64
Accounts Receivable Advertising	4,535.62	4,682.66
Accounts Receivable Dues		126.45
Accounts Receivable Manuals	25.00	30.00
Investments	25,699.44	31,263.32
Inventory, Manuals	45.00	7.50
Office Equipment (Depreciated)	2,078.70	1,870.83
Total Assets	$35,267.90	$38,372.40
Less:		
Annual Dues, Advance Payments	$360.24	$473.75
Total Assets Representing Surplus	$34,907.66	$37,898.65
Composed as follows:		
Surplus, Last Report	$29,799.66	$36,124.59
Addition to Surplus	5,108.00	1,774.06
	$34,907.66	$37,898.65

Statement of income and expenditure

	Year Ending December 31, 1931	Year Ending December 31, 1932
Income:		
Annual Dues	$31,010.45	$26,971.05
Initiation Fees	1,060.00	624.70
Advertising	23,157.82	17,372.78
Subscriptions to Journal	2,260.40	2,385.02
Sales of Proceedings	133.32	186.16
Sales of Specifications	116.10	61.00
Sales of Manuals	335.00	345.00
Royalties on Manual Sales	144.50	104.00
Interest on Investments	1,356.39	1,765.68
Interest on Deposits	97.57	59.60
Convention Registration Fees	5,380.00	3,280.00
Annual Payment by Water Works Manufacturers Association	7,500.00	7,500.00
Reimbursement for Office Expense by Sectional Committee on Cast Iron Pipe	799.98	800.02
Reprints	616.13	540.84
Sundries	41.07	167.03
Total Income	$74,008.73	$62,162.88
Expenditure:		
Convention Entertainment Expense	$4,410.79	$3,092.33
Convention Expense (balance)	$2,309.88	2,469.10
Office Expense	7,126.17	5,929.76
Committee Expense	2,948.99	3,315.08
Section and Division Expense	3,056.40	3,134.30
Directors' Meetings	1,367.86	1,151.64
Salaries	20,351.01	19,343.33
Manuals, Purchases	292.50	243.75
Printing Journal	25,542.40	20,089.67
Reprints	1,138.89	1,076.33
Specifications	63.57	215.29
Depreciation, Office Equipment	230.97	207.87
Sundries	61.30	120.37
Total Expenditure	$68,900.73	$60,388.82
Excess of Income over Expenditure	$5,108.00	$1,774.06

I certify that the above two statements are in accordance with the books and correct.

(Signed) A. B. Dorer,
Certified Public Accountant,
170 Broadway, New York, N. Y.

Membership statement for years 1931 and 1932

	ACTIVE	CORPORATE	ASSOCIATE	HONORARY	TOTAL
January 1, 1931	2,367	221	225	18	2,831
January 1, 1932	2,279	212	209	17	2,717
Gains during 1932:					
New Members	98	14	5		117
Restored	20		2		22
	2,397	226	216	17	2,856
Losses during 1932:					
Resignations	110	9	22		141
Deaths	27			1	28
Dropped for Non-payment of Dues December 31, 1932	264	10	23		297
Total Losses	401	19	45	1	466
Total December 31, 1932	1,996	207	171	16	2,390
Total January 1, 1932	2,279	212	209	17	2,717
Loss in Year 1932	283	5	38	1	327

Comparative statement—gains and losses—five-year period

YEAR	NEW	RESTORED	RESIGNATIONS	DEATHS	DROPPED FOR NON-PAYMENT OF DUES	GAIN OR LOSS
1932	117	22	141	28	297	−327
1931	203	22	98	25	216	−114
1930	501	39	95	26	134	+285
1929	314	25	94	24	130	+91
1928	203	36	86	13	126	+14
Totals—5-year period	1,338	144	514	116	903	−51

TYPHOID FEVER IN THE LARGE CITIES OF THE UNITED STATES IN 1932[1]

This report concerns the same ninety-three cities with a population of more than 100,000 that appeared in the corresponding report for 1931. The number of deaths from typhoid during 1932 in each city (except Scranton, as explained in note to table 2) has been supplied by the respective health department. The rates are calculated on the basis of the population figures for July 1, 1932, as estimated by the United States Bureau of the Census, except in the few instances (noted in the tables) in which such estimates were not made; in the latter, the population figures of the 1930 federal census were employed.

It should be noted that the figures for deaths from typhoid include all that have occurred within the city limits, those of nonresidents as well as of residents. It is greatly to be desired that more information should be placed on record respecting the place of residence of decedents, since it is evident that the present statistical practice of tabulating deaths according to the locality in which they happen to occur may lead to mistaken conclusions. At present there is no doubt that the nonresident deaths from typhoid constitute an important problem in a number of localities. So far as information is afforded us, we have indicated in table 9 those cities in which one third or more of the typhoid deaths in 1932 occurred in nonresidents.[2] Perhaps some day it may be possible to obtain the yet more important information as to the locality where the typhoid infection was contracted, although under present conditions, even in New York City, less than half the cases can be traced to their source.

[1] Reprinted from the Journal of the American Medical Association, 100: 19, May 13, 1933, page 1491. The preceding articles were published in the same Journal, May 31, 1913, p. 1702; May 9, 1914, p. 1473; April 17, 1915, p. 1322; April 22, 1916, p. 1305; March 17, 1917, p. 845; March 16, 1918, p. 777; April 5, 1919, p. 997; March 6, 1920, p. 672; March 26, 1921, p. 860; March 25, 1922, p. 890; March 10, 1923, p. 691; Feb. 2, 1924, p. 389; March 14, 1925, p. 813; March 27, 1926, p. 948; April 9, 1927, p. 1148; May 19, 1928, p. 1624; May 18, 1929, p. 1674; May 17, 1930, p. 1574; May 9, 1931, p. 1576, and April 30, 1932, p. 1550.

[2] The problem of the nonresident in typhoid statistics is discussed more at length in J. A. M. A. 98: 1550 [April 30] 1923.

So far as we have been able to ascertain, tables 1–8 contain rates for all the years since 1906 for which typhoid deaths are available in the records of the health departments of the respective cities. Certain of the five-year averages for the individual cities are based on figures for less than five of the years indicated. These irregularities have heretofore been marked by footnotes giving the missing years for each city. To clarify the tables, the specific footnotes are replaced in the present report (and the practice will probably be continued in the future) by the simple note, "Incomplete data." The

TABLE 1

Death rates of fourteen cities in New England states from typhoid per hundred thousand of population

	1932	1931	1930	1926–1930	1921–1925	1916–1920	1911–1915	1906–1910
Bridgeport	0.0	0.7	0.0	0.5	2.2	4.8	5.0	10.3
Fall River	0.0*	0.0	2.6	2.2	2.3	8.5	13.4	13.5
Lynn	0.0	0.0	1.0	1.5	1.6	3.9	7.2	14.1
New Bedford	0.0*	1.8	2.7	1.5	1.7	6.0	15.0	16.1
Somerville	0.0	0.0	1.9	1.3	1.6	2.8	7.9	12.1
Waterbury	0.0	0.0	1.0	1.2	1.0	8.0	18.8	
Boston	0.5	0.9	0.8	1.2	2.2	2.5	9.0	16.0
Hartford	0.6	3.6	2.4	1.3	2.5	6.0	15.0	19.0
Providence	0.8	1.6	2.0	1.3	1.8	3.8	8.7	21.5
New Haven	1.2	1.2	0.0	0.6	4.4	6.8	18.2	30.8
Worcester	1.5	0.5	0.0	1.0	2.3	3.5	5.0	11.8
Cambridge	1.7	0.0	0.9	2.1	4.3	2.5	4.0	9.8
Springfield	1.9	2.6	0.7	0.4	2.0	4.4	17.6	19.9
Lowell	2.0*	1.0	5.0	2.6	2.4	5.2	10.2	13.9

* Rate computed from population as of April 1, 1930, as no estimate for July 1, 1932, was made by the Census Bureau.

years which are included in the five-year averages, but for which typhoid mortality data are lacking, are as follows: Akron, 1906, 1907, 1908; Chattanooga, 1911, 1912, 1913; Fort Worth, 1918, 1919; Houston, 1906, 1907, 1908, 1909; Kansas City, Kan., 1906, 1907; Knoxville, 1916, 1917, 1918, 1919; Long Beach, 1921; Oklahoma City, 1926; Peoria, 1907, 1908 and the first four months of 1909; Tampa, 1916; Tulsa, 1921, 1922; Utica, 1921, 1922, 1923, 1924; Wilmington, 1913, 1917, 1918, 1919, 1920.

In the large New England cities, typhoid is rapidly becoming an almost negligible disease (table 1). Six cities in this group (Bridge-

port, Fall River, Lynn, New Bedford, Somerville and Waterbury), with an aggregate population of 686,271, reported not a single death from typhoid during 1932, four of these having clean slates for two years in succession. Boston records the lowest typhoid rate in its history (0.5), less than half its average for the period 1926–1930. Springfield, which ranked best among the New England cities in the latest five-year average, apparently did not do so well in 1931 and

TABLE 2

Death rates of eighteen cities in Middle Atlantic states from typhoid per hundred thousand of population

	1932	1931	1930	1926–1930	1921–1925	1916–1920	1911–1915	1906–1910
Elizabeth	0.0	4.3	4.4	1.6	2.4	3.3	8.0	16.6
Rochester	0.3	0.9	1.8	1.7	2.1	2.9	9.6	12.8
Syracuse	0.5	0.5	0.5	0.8	2.3	7.7	12.3	15.6
Jersey City	0.6	0.3	0.3	0.9	2.7	4.5	7.2	12.6
Paterson	0.7	2.9	0.0	1.0	3.3	4.1	9.1	19.3
Yonkers	0.7	1.4	0.7	0.5	1.7	4.8	5.0	10.3
Albany	0.8	2.3	0.8	1.8	5.6	8.0	18.6	17.4
New York	0.8	1.1	0.9	1.3	2.6	3.2	8.0	13.5
Trenton	0.8	1.6	2.4	2.1	8.2	8.6	22.3	28.1
Newark	0.9	0.2	0.2	0.9	2.3	3.3	6.8	14.6
Reading	0.9	0.0	0.9	1.6	6.0	10.0	31.9	42.0
Buffalo	1.2	0.7	1.9	2.7	3.9	8.1	15.4	22.8
Philadelphia	1.3	0.9	0.9	1.1	2.2	4.9	11.2	41.7
Pittsburgh	1.3	1.2	1.5	2.4	3.9	7.7	15.9	65.0
Scranton	1.4*	2.1	1.4	1.8	2.4	3.8	9.3	31.5
Erie	1.7	0.8	0.9	0.9	2.3	6.9	49.0	46.6
Utica	1.9	0.0	0.0	1.1	3.9†			
Camden	2.5	4.2	4.2	4.4	5.9	4.9	4.5	4.0

* Typhoid deaths for Scranton furnished by Pennsylvania Department of Health, Harrisburg.

† Incomplete data.

1932. Is there a small typhoid focus (a carrier?) in or about Springfield? Lowell, which showed no improvement in 1926–1930 over 1921–1925, has done no better in 1930–1932.

The typhoid rate for the New England group as a whole reaches a new low point and is equaled only by the cities of the East North Central states (table 4).

The cities in the Middle Atlantic states, for the most part, bettered their excellent record of 1931 (table 2). The city of Elizabeth,

TABLE 3

Death rates of nine cities in South Atlantic states from typhoid per hundred thousand of population

	1932	1931	1930	1926–1930	1921–1925	1916–1920	1911–1915	1906–1910
Baltimore	0.6	3.1	3.3	3.2	4.0	11.8	23.7	35.1
Norfolk	0.8*	5.4	3.8	2.2	2.8	8.8	21.7	42.1
Wilmington	0.9*	1.9	4.7	3.1	4.7	25.8†	23.2†	33.0
Washington	1.4	3.9	3.3	2.8	5.4	9.5	17.2	36.7
Miami	1.8	1.8	1.8	3.5				
Richmond	2.7	1.6	2.2	1.9	5.7	9.7	15.7	34.0
Jacksonville	2.8	3.0	0.0	4.4				
Tampa	2.8	3.8	3.0	3.8	19.1	43.9†		
Atlanta	8.8	12.6	10.3	11.1	14.5	14.2	31.4	58.4

* Rate computed from population as of April 1, 1930, as no estimate for July 1, 1932, was made by the Census Bureau.

† Incomplete data.

TABLE 4

Death rates of eighteen cities in East North Central states from typhoid per hundred thousand of population

	1932	1931	1930	1926–1930	1921–1925	1916–1920	1911–1915	1906–1910
Grand Rapids	0.0	1.2	0.6	1.0	1.9	9.1	25.5	29.7
Milwaukee	0.0	0.3	0.3	0.8	1.6	6.5	13.6	27.0
South Bend	0.0	0.0	0.0					
Cleveland	0.2	3.4	1.5	1.0	2.0	4.0	10.0	15.7
Akron	0.4	1.5	1.2	1.5	2.4	10.6	21.0	27.7†
Chicago	0.4	0.4	0.6	0.6	1.4	2.4	8.2	15.8
Detroit	0.5	0.7	1.1	1.3	4.1	8.1	15.4	22.8
Toledo	0.7	2.0	2.1	3.0	5.8	10.6	31.4	37.5
Canton	0.9	1.9	1.9	1.4	3.3	8.9		
Dayton	1.0	0.4	0.5	1.9	3.3	9.3	14.8	22.5
Youngstown	1.1	1.7	2.3	1.1	7.2	19.2	29.5	35.1
Indianapolis	1.6	1.6	1.9	2.7	4.6	10.3	20.5	30.4
Columbus	1.7	2.4	2.7	2.1	3.5	7.1	15.8	40.0
Flint	1.8	0.0	0.6	1.6	4.6	22.7	18.8	46.9
Peoria	1.8	1.8	0.0	0.2	3.7	5.7	16.4	15.7†
Evansville	1.9	0.9	6.8	6.2	5.0	17.5	32.0	35.0
Fort Wayne	2.5	1.7	2.6	4.2	12.9	7.3		
Cincinnati	3.0	0.4	2.4	2.5	3.2	3.4	7.8	30.1

† Incomplete data.

which heads the list with a complete freedom from typhoid mortality, also reports the entire absence of typhoid cases within its borders.

This is a marked improvement over the two preceding years. New York City again registered a very low typhoid rate. Camden, although showing some improvement, once more brings up at the foot of the list.

The cities in the South Atlantic group (table 3) show the largest proportional reduction in 1932 of any geographic division. Only one of the nine cities (Richmond) had even a slight typhoid increase over the preceding year. Baltimore's typhoid drops to a new low point and compares favorably with that of any other city of its size in the country. Washington, Norfolk and Atlanta also record notable improvement. The strides in typhoid elimination taken by this group of cities in the past few years offer a conclusive answer to those sanitarians who, not so very long ago, were maintaining that typhoid must inevitably remain relatively high in a warm climate.

TABLE 5

Death rates of six cities in East South Central states from typhoid per hundred thousand of population

	1932	1931	1930	1926–1930	1921–1925	1916–1920	1911–1915	1906–1910
Birmingham	2.5	3.0	4.6	8.0	10.8	31.5	41.3	41.7
Louisville	2.9	2.6	1.6	3.7	4.9	9.7	19.7	52.7
Nashville	7.6	3.2	12.3	18.2	17.8	20.7	40.2	61.2
Chattanooga	8.0	1.6	0.8	8.0	18.6	27.2	35.8†	
Knoxville	8.0	7.3	1.9	10.7	20.8	25.3†		
Memphis	11.4	7.3	4.7	9.3	18.9	27.7	42.5	35.3

† Incomplete data.

In 1932 Baltimore ranks comfortably alongside Boston, a really great achievement in public health.

The cities of the East North Central group (table 4) continue to have the lowest typhoid average of any geographic division, although closely pressed by the New England cities. Milwaukee is, we believe, the largest city in the country to get through a calendar year without a single death from typhoid, and South Bend is apparently the first city to have a perfect typhoid record over a period of three consecutive years. The reason for the contrast between South Bend and Fort Wayne, might bear looking into. The three most populous cities in this group, Chicago, Cleveland and Detroit, make remarkable records.

The cities of the East South Central group (table 5) although the

lowest population aggregate, have the highest typhoid rate of any geographic division of the United States. This is also the only geographic division in the country to register a higher typhoid rate for 1932 than for 1931. In 1932, five of the six cities showed a more or less considerable increase over 1931. Birmingham constitutes a notable exception and registers progressive improvement since 1929. The city of Chattanooga is one of the few places in the country in which the 1932 rate might be said to be of almost epidemic proportion compared with the year immediately preceding. The city of Memphis, in this group, occupies the unenviable position of leading all the American cities in typhoid mortality in 1932. The cities of the East South Central states may well take heart from what has been

TABLE 6

Death rates of nine cities in West North Central states from typhoid per hundred thousand of population

	1932	1931	1930	1926–1930	1921–1925	1916–1920	1911–1915	1906–1910
Des Moines	0.0	0.0	1.4	2.4	2.2	6.4	15.9	23.7
Kansas City, Kan	0.0	1.6	0.0	1.7	5.0	9.4	31.1	74.5†
St. Paul	0.7	1.1	0.7	1.4	3.4	3.1	9.2	12.8
Minneapolis	0.8	0.6	1.3	0.8	1.9	5.0	10.6	32.1
Duluth	1.0	1.0	2.0	1.1	1.7	4.4	19.8	45.5
St. Louis	1.2	2.0	2.5	2.1	3.9	6.5	12.1	14.7
Kansas City, Mo	1.4	1.5	2.2	2.8	5.7	10.6	16.2	35.6
Omaha	1.4	1.8	0.9	1.3	3.3	5.7	14.9	40.7
Wichita	1.7	0.0	1.8	1.2	6.3			

† Incomplete data.

accomplished in the South Atlantic states. What Baltimore and Washington have achieved, Nashville and Memphis may well look forward to. The conspicuous position of this section of the country in respect to typhoid mortality can hardly be a matter of weather, poverty or unpreventable accident.

The nine cities of the West North Central states (table 6) once more break their own excellent group record. Des Moines has a perfect score for two years running and no city in the group reports a rate as high as 2 per hundred thousand of population. The low rate in St. Louis is worthy of special mention. It seems almost incredible that Kansas City, Kan., which had an average mortality rate of 74.5 for 1906–1910, should have no deaths at all from typhoid

only twenty-five years later, in 1932. Duluth and Omaha have also shown remarkable improvement.

Several of the cities in the West South Central states (tabl· 7) show improved typhoid rates for 1932 as compared with 1931, so that

TABLE 7

Death rates of eight cities in West South Central states from typhoid per hundred thousand of population

	1932	1931	1930	1926–1930	1921–1925	1916–1920	1911–1915	1906–1910
Tulsa	0.0	2.0	2.1	8.3	16.2†			
Fort Worth	2.9	5.4	4.9	5.9	6.1	16.3†	11.9	27.8
San Antonio	3.6	4.2	3.9	4.6	9.3	23.3	29.5	35.9
Houston	3.7	3.2	3.8	4.8	7.6	14.2	38.1	49.5†
Oklahoma City	3.9	5.6	7.0	7.4†				
El Paso	5.6	4.8	6.8	9.1	10.8	30.7	42.8	
Dallas	7.4	7.3	6.5	7.3	11.2	17.2		
New Orleans	8.6	13.9	6.5	9.9	11.6	17.5	20.9	35.6

† Incomplete data.

TABLE 8

Death rates of eleven cities in Mountain and Pacific states from typhoid per hundred thousand of population

	1932	1931	1930	1926–1930	1921–1925	1916–1920	1911–1915	1906–1910
Long Beach	0.0	0.0	0.7	1.1	2.1†			
Los Angeles	0.6	0.7	1.5	1.5	3.0	3.6	10.7	19.0
Portland	0.6	1.0	1.0	2.3	3.5	4.5	10.8	23.2
San Diego	0.6	0.6	0.0	1.0	1.6	7.9	17.0	10.8
Denver	0.7	3.4	2.1	2.6	5.1	5.8	12.0	37.5
Salt Lake City	0.7	1.4	2.8	1.9	6.0	9.3	13.2	41.1
Oakland	1.0	1.0	1.0	1.2	2.0	3.8	8.7	21.5
Seattle	1.1	0.5	2.2	2.2	2.6	2.9	5.7	25.2
San Francisco	1.5	1.4	1.3	2.0	2.8	4.6	13.6	26.3
Spokane	1.7	0.8	1.7	2.2	4.4	4.9	17.1	50.3
Tacoma	1.8	0.9	0.9	1.8	3.7	2.9	10.4	19.0

† Incomplete data.

the group average is definitely lower. The rate for this group of cities is, however, still far too high. The actual number of tyhpoid deaths (102) for the population of not quite two million (1,961,700) is nearly double that for the South Atlantic group (53) with a population considerably greater (2,375,507), and the rate is more than seven

TABLE 9

Death rates from typhoid in 1932

Honor Roll: No typhoid death (fourteen cities)

Bridgeport	Kansas City, Kan.	Somerville
Des Moines	Long Beach	South Bend
Elizabeth	Lynn	Tulsa
Fall River	Milwaukee	Waterbury
Grand Rapids	New Bedford	

First Rank (from 0.1 to 1.9 deaths per hundred thousand, fifty-eight cities)

Cleveland	0.2	Minneapolis	0.8	Kansas City, Mo.	1.4†
Rochester	0.3*	New York	0.8	Omaha	1.4†
Akron	0.4	Norfolk	0.8	Scranton	1.4*
Chicago	0.4	Providence	0.8†	Washington	1.4
Boston	0.5	Trenton	0.8*	San Francisco	1.5†
Detroit	0.5	Canton	0.9	Worcester	1.5
Syracuse	0.5*	Newark	0.9	Indianapolis	1.6†
Baltimore	0.6†	Reading	0.9	Cambridge	1.7
Hartford	0.6*	Wilmington	0.9	Columbus	1.7†
Jersey City	0.6*	Dayton	1.0†	Erie	1.7
Los Angeles	0.6†	Duluth	1.0*	Spokane	1.7
Portland	0.6	Oakland	1.0†	Wichita	1.7†
San Diego	0.6*	Seattle	1.0	Flint	1.8†
Denver	0.7	Youngstown	1.1†	Miami	1.8
Paterson	0.7	Buffalo	1.2†	Peoria	1.8†
St. Paul	0.7	New Haven	1.2	Tacoma	1.8
Salt Lake City	0.7	St. Louis	1.2	Evansville	1.9
Toledo	0.7	Philadelphia	1.3	Springfield	1.9*
Yonkers	0.7	Pittsburgh	1.3†	Utica	1.9†
Albany	0.8*				

Second Rank (from 2.0 to 4.9, thirteen cities)

Lowell	2.0	Jacksonville	2.8†	Cincinnati	3.0†
Birmingham	2.5†	Tampa	2.8	San Antonio	3.6†
Camden	2.5†	Fort Worth	2.9	Houston	3.7†
Fort Wayne	2.5	Louisville	2.9	Oklahoma City	3.9
Richmond	2.7				

Third Rank (from 5.0 to 9.9, seven cities)

El Paso	5.6†	Nashville	7.6†	New Orleans	8.6
Dallas	7.4	Chattanooga	8.0	Atlanta	8.8
		Knoxville	8.0†		

Fourth Rank (10.0 and over)

Memphis	11.4†

* All the typhoid deaths reported were stated to be in nonresidents.

† One-third or more of the reported typhoid deaths were stated to be in nonresidents.

times as great as that for the New England and East North Central cities. The record of the city of Tulsa for the past three years stands out a shining exception to that of the other cities of this division. New Orleans is evidently finding it a hard job to reduce its typhoid materially.

The city of Dallas, in a detailed epidemiologic study, reports that nearly a third of the typhoid deaths registered in that city were those of nonresidents. Since emphasis is laid on a similar distinction by several city health officers, it seems worth while to note that we have on other occasions pointed out that typhoid is today a regional rather than a strictly municipal problem. The occurrence of typhoid cases

TABLE 10

Number of cities with various typhoid death rates

	NUMBER OF CITIES	10.0 AND OVER	5.0 TO 9.9	2.0 TO 4.9	1.0 TO 1.9	0.1 TO 0.9	0.0
1916–1910	77	75	2	0	0	0	0
1911–1915	79	58	19	2	0	0	0
1916–1920	84	22	32	30	0	0	0
1921–1925	89	12	17	48	12	0	0
1926–1930	92	3	10	30	37	12	0
1926	91	9	13	28	20	15	6
1927	92	6	10	28	27	13	8
1928	92	5	9	29	22	17	10
1929	92	2	9	21	27	25	8
1930	93	2	6	30	23	22	10
1931	93	2	6	23	28	22	12
1932	93	1	7	13	29	29	14

and deaths in suburban areas just outside the political boundaries of a city cannot be ignored as a factor affecting city typhoid rates. A ring of typhoid foci around a city is, of course, a menace to the health of the city itself. Polluted bathing beaches frequented by city residents must always be a matter of concern to health officials, even if not located within the city borders. Practically, if not technically, these outside sources of infection are subject to some measure of city control. Experience in other sections of the country has shown that a reduction in typhoid within a city has been followed by a lessening of the amount of typhoid in the country round about. The Dallas report also dwells on the relatively high typhoid rate in the Negro population of that city. While there is no doubt that a high pro-

portion of Negroes in a city tends to swell the total typhoid rate, it is only necessary to point to examples like those of Baltimore and Richmond to show that this difficulty is not insurmountable. Typhoid is an environmental, not a racial, disease. There does not

TABLE 11

*Total typhoid rate for seventy-eight cities, 1910–1932**

	POPULATION	TYPHOID DEATHS	TYPHOID DEATH RATE PER 100,000
1910	22,573,435	4,637	20.54
1911	23,211,341	3,950	17.02
1912	23,835,399	3,132	13.14
1913	24,457,989	3,285	13.43
1914	25,091,112	2,781	11.08
1915	25,713,346	2,434	9.47
1916	26,257,550	2,191	8.34
1917	26,865,408	2,016	7.50
1918	27,086,696†	1,824†	6.73
1919	27,735,083†	1,151†	4.15
1920	28,244,878	1,088	3.85
1921	28,859,062	1,141	3.95
1922	29,473,246	963	3.26
1923	30,087,430	950	3.16
1924	30,701,614	943	3.07
1925	31,315,598	1,079	3.44
1926	31,929,782	907	2.84
1927	32,543,966	648	1.99
1928	33,158,150	628	1.89
1929	33,772,334	537	1.59
1930	34,386,717	554	1.61
1931	35,137,915	563	1.60
1932	35,691,815	442	1.24‡

* The following fifteen cities are omitted from this table because data for the full period are not available: Canton, Chattanooga, Dallas, Fort Wayne, Jacksonville, Knoxville, Long Beach, Miami, Oklahoma City, South Bend, Tampa, Tulsa, Utica, Wichita, Wilmington.

† Data for Fort Worth lacking.

‡ The rate for the ninety-three cities in 1932 is 1.34 (total population, 37,753,512; typhoid deaths, 508), whereas in 1930 the corresponding rate was 1.64, and in 1931, 1.68.

seem to be any real reason why Dallas should continue to have a typhoid rate nearly twice as high as that of San Antonio.

The cities in the Mountain and Pacific states (table 8) make an excellent record, lowering the group rate to the lowest point yet

reached. The two-year perfect record in Long Beach is remarkable. Denver, after an aberration in 1931, is again in line with the other cities of the group. It seems to be true that typhoid is fast disappearing in this section of the country.

The total typhoid rate for the seventy-eight cities in our survey (table 11) is the lowest ever recorded (1.24) and makes a gratifying decrease over the three preceding years. As many as fourteen cities registered entire freedom from typhoid deaths for the calendar year 1932, an unprecedented record. The practically complete eradication of typhoid over wide areas of the United States seems a goal worth striving for.

TABLE 12

Total typhoid death rate for hundred thousand of population for ninety-three cities according to geographic divisions

	1932 POPULATION	TYPHOID DEATHS		TYPHOID DEATH RATES			
		1932	1931	1932	1931	1926–1930	1925
New England	2,631,505	19	28	0.72	1.07	1.31	2.48
Middle Atlantic	13,038,300	126	137	0.97	1.06	1.40	2.97
South Atlantic	2,375,507	53	101	2.23	4.29	4.50	7.01*
East North Central	9,759,600	68	96	0.70	1.00	1.29†	2.32†
East South Central	1,242,500	77	50	6.20	4.09	8.31	13.00
West North Central	2,720,700	28	36	1.03	1.34	1.83	3.43
West South Central	1,961,700	102	133	5.20	6.97	7.32‡	13.08‖
Mountain and Pacific	4,023,700	35	42	0.87	1.07	1.80	2.33

* Lacks data for Jacksonville and Miami.

† Data for South Bend for 1925–1929 are not available.

‡ Lacks data for Oklahoma City in 1926.

‖ Lacks data for Oklahoma City.

The low typhoid record of American cities in 1932 is worth special notice, since in the autumn disquieting reports were current about the exacerbation of the infection. In August the prevalence of typhoid in Illinois was said to be higher than at that time of year for more than a decade. A statement published by *Science Service*, Washington, D. C., reported (Aug. 19) that "typhoid fever is increasing all over the nation" and suggested that this condition might be "due to certain laxity in sanitary procedure." Whatever the case as regards rural communities and the smaller cities, it is evident, now that the returns are all in, that the larger cities of the United States experienced no increase in typhoid mortality in 1932 but, instead, a substantial reduction.

It is to be hoped that the achievements of public health workers in combating typhoid in the United States will receive the attention from publicists that they deserve. The unceasing vigilance that has been necessary to prevent the increase of typhoid in some localities and to bring about an actual reduction in others can hardly be realized by those not concerned with the details of public health administration. In these days of slipping appropriations and curtailed personnel, it is no small triumph for the health officers of this country that they not only have prevented an increase of typhoid but also have actually brought about a considerable reduction. Civilized standards of disease prevention give no indication of being undermined.

ABSTRACTS OF WATER WORKS LITERATURE[1]

FRANK HANNAN

Key: American Journal of Public Health, 12: 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to the page of the Journal.

Tests for Color and Alkalinity. CHAS. R. COX. Water Work Eng., 85: 7, 368, April 6, 1932. Coloring material in water, although in itself harmless, is unpleasing to consumer. Removal of color with alum is decidedly sensitive to pH change and should be effected at optimum point, which usually lies between pH 4.6 and 6.2. Complete directions for preparation of color standards and for determination of color are given. Alkalinity of filtered water must be known for intelligent use to be made of soda ash, or lime, to prevent corrosion. Details are given for its determination; likewise jar method for control of coagulation.—*Lewis V. Carpenter.*

Colored Well Water Treated at Los Angeles Purification Plant. Anon. Water Works Eng., 85: 7, 380, April, 6, 1932. Ferric chloride is coagulant used at Wilmington plant of Los Angeles supply. Water comes from wells; is of amber color; and contains much organic matter and hydrogen sulphide. Raw water is super-chlorinated and ferric chloride added: after mixing, it flows over weir to clarifier, sludge from which is pumped back to mixers so that no unused ferric chloride therein contained may be lost. Filters have following innovations: glass observation panels in each unit; depth of coarse sand only 10 inches; and distribution of influent wash water through grid with orifices delivering parallel to sand surface. Back washing takes from one to two minutes.—*Lewis V. Carpenter.*

Small Town Water System. C. N. HARRUB. Water Works Eng., 85: 14, 851, July 13, 1932. New water system of Walton, Ky., was completed August 1931 at cost of $35,000. Water is impounded by rip-rapped earth dam with concrete spillway. Provision is made for drawing water at two levels. Treatment consists of alum dosage followed by settling basins. Chlorine is added just prior to pumping. Provision is made for future filters. Pressure is maintained by 100,000-gallon elevated tank. Distribution system is of cast iron pipe with copper service connections throughout.—*Lewis V. Carpenter.*

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[1] Vacancies on the abstracting staff occur from time to time. Members desirous of coöperating in this work are earnestly requested to communicate with the chief abstractor, Frank Hannan, 285 Willow Avenue, Toronto 8, Ontario, Canada.

The Water Systems of Java. WALTER BUCHLER. Water Works Eng., 85: 15, 898, July 27, 1932. Modern water works are now of 30 years standing in Java. Before that, shallow wells and rivers were used and severe epidemics of cholera were prevalent. Between 50 and 60 large towns now have water systems. Soerabaya, the commercial center, gets part of its water from closed wells in mountains and part from river. Mountain supply receives no treatment. River water is treated in 2-m.g.d. rapid sand filter plant using alum as coagulant. Water is super-cholorinated and excess chlorine removed by sodium bisulphite. System also includes two reservoirs with combined capacity of 5 million gallons. Cast iron is used in distribution system for larger sized pipe and galvanzied iron for smaller. All pipes are underlain with sand bed for drainage purposes. Distribution in native sections was formerly by hydrants; due to laziness and carelessness, much water was wasted. It was then piped to homes of water sellers, who distributed it in cans. These charged such excessive rates (5 cents for 8 gallons, minimum) that finally coin-operated meters were installed, which supply 9 gallons for every cent inserted. In addition to private connections, community has installed between 200 and 300 bathing houses using similar meters. Europeans' homes have Western type water connections. Water-borne disease is practically extinct.—*Lewis V. Carpenter.*

Laws Regulating Sale of Water. LEO T. PARKER. Water Works Eng., 85: 15, 901, July 27, 1932. Municipality has right to supply water to non-residents, providing it can also supply its residents. Right to sell water is not prerogative of government, but is a business in which any person may engage without legislative authority. It is only with respect to special use of streets for pipes, mains, etc., that grant from state, or its subdivisions, is necessary. Water rates can not be considered as taxation. Bond issue for improvement of water works plant is valid, although land and machinery of combined water works and electric light plant, and income derived therefrom, are to be utilized as payment for improvement. City council are rightfully entitled to determine, without reference to electorate, whether property should be purchased, or obtained by condemnation proceedings. Board of trustees are not required to submit to electors a franchise which they as a board do not approve. Generally speaking, water company may be compelled to extend its service so as to render adequate supply to prospective water users. However, under no circumstances may water company be compelled to connect its mains to mains owned by private property owner, unless latter pays water company a reasonable sum for the service.—*Lewis V. Carpenter.*

The Water Supply of Toledo. R. W. FURMAN. Water Works Eng., 85: 14, 846, July 13, 1932. Source of supply is Maumee River, which is sluggish, with many impounding dams; ideal conditions for growth of plant and animal organisms. Water is alkaline, moderately hard, and relatively high in bacterial count. Tastes and odors due to algae and to organic decomposition products have given much trouble for past twenty years, being worse in summer months. Aluminum sulfate, caustic lime, and liquid chlorine are used in purification processes, besides activated carbon for elimination of tastes and odors. Very

careful chemical dosage is necessary, as poor floc concurrently with high algae may shorten filter runs to as low as three hours. Treatment with 1.5 g.p.g. aluminum sulfate, 0.5 g.p.g. lime (CaO), and 2 p.p.m. activated carbon is sufficient to remove all tastes and odors. Less activated carbon can generally be used. During summer of 1931, before activated carbon was used, filter runs were reduced to three-hour periods. Sedimentation basins had to be cleaned at ten-day intervals, on account of odors. Activated carbon was applied at rate of 1.7 p.p.m. by mixing it with 5 per cent solution of aluminum sulfate, to effluent from low-lift pumps just before lime was added and before entry to mixing and sedimentation basins. Although more activated carbon was thus used than application after sedimentation basins would have required, stabilization of sludge justified this procedure. Series of tests was made on an individual filter, applying suspension of activated carbon to top of filter, control filter without such addition being run beside it. Treatments as high as 28.5 p.p.m. were applied without serious shortening of filter runs. This is clearly shown in table giving loss of head per hour for each dosage applied and corresponding loss of head per hour in control filter. *Lewis V. Carpenter.*

The Springfield, Mass., Water Supply. Anon. Water Works Engineering, 85: 19, 1136, September 21, 1932. Main supply is taken from Westfield Little River which has drainage area of 48.5 square miles. There are two storage reservoirs, Borden Brook and Cobble Mountain, with respective capacities of 2½ and 22½ billion gallons. Water is filtered at source of supply and delivered into clear water reservoirs with capacities of 17 and of 12 m.g., respectively. City pressure is about 140 pounds.—*Lewis V. Carpenter.*

Small Town Water Supply. Frank S. Cobb. Water Works Engineering, 85: 19, 1128, September 21, 1932. Well built plant had been allowed to deteriorate badly: when author took it over, water was turbid and corrosive and had bad tastes and odors in summer; all hot water was red; power bill exceeded $600 per month; plant ran 24 hours per day; filters were full of mud balls and cracks; and only 100 out of 750 meters were being read and no repairs had been made on them for nine years. After improvements effected, power bill was reduced to $389 per month, and plant operation to 16 hours per day. Sludge amounting to 25 percent of capacity of settling tank was removed; filter underdrains were renewed; and sand cleaned. Monthly income was increased 40 percent. Over 10 percent of consumers were added to books who had previously been getting their water free. Meters were removed, rated, and repaired. In six months, Water Company was placed on firm financial footing, netting a profit of over 28 percent of gross revenue each month.—*Lewis V. Carpenter.*

Colombo's Water System. Walter Buchler. Water Works Engineering, 85: 19, 1126, September 21, 1932. Colombo, the capital of Ceylon, has population of 300,000. Rainfall averages 160 inches. Water system consists of 1900-million-gallon reservoir with catchment area of 2500 acres. Catchment area is devoid of habitation or cultivation. Two 20-inch cast iron and one 30-inch steel mains, 28 miles long, bring water to two 8-million-gallon reservoirs in city.

Water is treated with alum and filtered. Distribution system totals 257 miles. No pumping is necessary. All houses have service connections except tenements which have a common water-tap. There are 300 street taps for pedestrians and poorer class. City furnishes 10 million gallons of water a month to steamers.—*Lewis V. Carpenter.*

B. Typhosus is Waiting for You. NATHAN N. WOLPERT. Water Works Engineering, 85: 19, 1122, September 21, 1932. *Bacillus typhosus* is unicellular organism, which enters the body through mouth, spreading into intestines and then into blood. Poisons given off by germ give rise to symptoms of disease. Four out of every five carriers are women. Incubation period is from 10 to 14 days. Animals are not susceptible. Number of typhoid fever outbreaks is fairly constant. Tables are included showing numbers of outbreaks, cases, and deaths in U. S. for 1920–1929; also, table showing death-rates of several European cities. Periods of floods and repairs are most dangerous. Epidemic started in Albany, N. Y., when Hudson River flooded filter plants April, 1913. Epidemic in Butler, Pa., in November, 1903, started after ten-day shut-down of filters while installing pump. Wells used because of turbidity of city water caused outbreak in Lynchburg, Va. Springs were also responsible for several cases. Break in main caused outbreak of 367 cases in Philadelphia in December 1911. Outbreak at Des Moines, Iowa, in December 1910 was caused by excessive scraping of filter beds. Responsibility rests upon all operators to keep their water free from water-borne diseases.—*Lewis V. Carpenter.*

Improved Customer Relations. EBEN F. PUTNAM. Water Works Engineering, 85: 17, 1002, August 24, 1932. Public relationships have not developed in water works field, because water works man has not had to sell his product. Careful routing of new mains may often prevent large amount of ill-will which will take months to overcome. Every employee should be sold on his company and should keep posted on all improvements and changes made. Best method of handling this is through company publication. It is poor economy to place a $15 to $18 clerk at cash window, as this person is main contact between company and customers. Metermen should be courteous, neat, and intelligent. All complaints should have immediate and courteous attention. Tact and thought are needed in collecting back bills and in keeping good-will of customer. Prevention of complaints is very important. Company men should affiliate with community activities. Use all publicity possible. Last, but not least, patronize local business men whenever possible.—*Lewis V. Carpenter.*

Unusual Filter Plant Features. F. JOHNSTONE-TAYLOR. Water Works Engineering, 85: 16, 952, August 10, 1932. Due to over-loading of present slow sand filters of London, England, supply, primary filters of rapid sand type have been installed, which enable slow sand filters to furnish safe water at three to four times previous rate. Experimental filters of approximately 10-m.g.d. capacity were first constructed and operated for two years. Rapid sand filters are of standard open type. Special feature is provision of sedimentation tanks below filters, where wash water is clarified before discharge into river. Sludge is used for fertilizer. Air-wash precedes water wash. Wash water consumption in experimental plant amounts to 0.43 percent.—*Lewis V. Carpenter.*

Experiences of a Small Town in Use of Concrete Reservoir. Samuel G. Wylie. Water Works Engineering, 85: 19, 1159, September 21, 1932. Due to proper consideration of design and construction, upkeep of concrete reservoir of city of Webster, Mass., has kept at $2 for fourteen years it has been in service. Although original cost of $19,970 was high, yearly cost to date has been but $1,426; while if reservoir lasts another thirty years, as predicted, annual cost will have been but $499.—*Lewis V. Carpenter.*

Corporation of Nottingham, England, Water Supply. Anon. Water and Water Engineering, 34: 400, 58–59, February 20, 1932. Covered reinforced concrete service reservoir is described. Division wall facilitates cleaning operations. Interior concrete was treated with sodium silicate before filling, to seal concrete face. Energy of water flowing into reservoir is utilized for driving turbine pump to raise water to supply properties above reservoir level. —*W. G. Carey.*

Cementing Constituents of Boiler Scale, Especially Silicates. F. Hundeshagen. Chemiker-Zeitung, 56: 521–524, 542–544, 1932. Hard scales are formed by $CaSO_4 \cdot 2H_2O$, $CaSO_4 \cdot 0.5H_2O$, calcium and mangesium hydroxide, and colloidal silica. Freshly precipitated magnesium hydroxide, especially in presence of alkali, is more effective for precipitation of silica than is calcium hydroxide. Softening with trisodium phosphate should only be used for removal of last traces of calcium and magnesium after precipitation of greater part as carbonate and hydroxide. Phosphate treatment of water softened with zeolite is unnecessary.—*W. G. Carey.*

Graphical Representation of the Composition of Waters. R. Frey. Annales de Chimie Analytique, 14: 49–57, 1932. From Chemistry and Industry, 51: 41, B 866, October 7, 1932. Mineral constituents of water are divided into six groups, carbonates, sulphates, and chlorides of alkalis and alkaline earths, concentrations being expressed in milligram-mols. By plotting these concentrations according to definite convention, using rectangular co-ordinates, two triangles may be constructed, (*a*) for carbonates and sulphates of alkalis and alkaline earths, and (*b*) for chlorides, areas of which give graphical representation of character of water. Diagrams for certain spa waters are given.—*W. G. Carey.*

Testing of Tap Water for Small Amounts of Lead and Copper. N. Schoorl. Zeitschrift für analytische Chemie, 88: 325–336, 1932. After determination of both metals together colorimetrically with sodium sulphide, color of copper being 1.5 times as intense as that of lead, lead is determined in separate portion with sodium sulphide after addition of ammonia, ammonium chloride, and potassium cyanide, and finally copper is determined alone colorimetrically with potassium ferrocyanide after addition of sodium bicarbonate. When amount of lead is very minute, one litre of water is made alkaline with sodium hydroxide and treated with potassium cyanide and 0.5 gm. of calcium carbonate. After shaking one hour the calcium carbonate containing all the lead is collected, dissolved in acetic acid, and tested as above. Minute amounts of copper may be collected similarly, using sodium hydroxide and magnesium chloride, precipi-

tated magnesium hydroxide being dissolved in sulphuric acid and filtered solution tested with potassium ferrocyanide.—*W. G. Carey.*

The Significance of B. Aërogenes in Water. A. GRAY. Journal of Hygiene, 32: 1, 1932. From Official Circular, British Waterworks Association, 14: 100, 419–420, June 1932. Significance of *B. aërogenes* in water was assessed by methyl red, VOGES-PROSKAUER and citrate tests. Study included (1) isolation from feces, (2) bacteriological examination of unpolluted soil, (3) proportions of *B. coli* and *B. aërogenes* in fresh and in stored tap water, and (4) examination of stored feces. Results showed that (*a*) *B. aërogenes* is practically universally present in human feces and has been isolated from feces of horse, cow, sheep, pig, dog, cat, rabbit, wild rat, and mouse; (*b*) modifications of citrate medium containing lithium or barium are useful when *B. pyocyaneus* is abundant; (*c*) *B. aërogenes* predominates over *B. coli* in soil in which fecal contamination unlikely, and *B. coli* isolated from such soil are indistinguishable from typical *B. coli*; (*d*) in Liverpool water, proportion of aërogenes to coli is high and increases on storage; (*e*) in water contaminated with feces, proportion of aërogenes to coli is low, but is reversed on storage, largely due to death of coli; and (*f*) preponderance of *B. aërogenes* over *B. coli* is indicative of contact with soil not contaminated with fresh feces, or long past contamination, and may be regarded as indicative of freedom from pathogenic organisms. Feces during storage showed marked increase followed by gradual decrease of total organisms present, decrease coinciding with increase in proportion of *B. aërogenes* to other organisms. Plea is made for uniformity in tests adopted for coliform organisms, and for exact statement of methods employed.—*W. G. Carey.*

Brownhill Reservoir of Batley, England, Corporation Waterworks. Anon. Water and Water Engineering, 34: 407, 400–406, August 20, 1932. Reservoir recently constructed has capacity of 266 million gallons and covers area of 24.7 acres. Embankment by which water is impounded is of earthwork, 700 feet long and 107 feet high, with impermeable core of puddled clay, founded on concrete with which central trench is filled. Concrete is carried considerable distance below ground, surrounding strata being impregnated with cement through boreholes. Discharge tunnel lined with concrete, driven through valley, and connected with valve shaft is means of water discharge.—*W. G. Carey.*

Some Hydrological Features of South West Africa. D. HOLTZHAUSEN. Water and Water Engineering, 34: 407, 395–400, August 20, 1932. Surface features, rainfall, including maximum and minimum annual rainfall, its periodicity, fluctuations, and intensity of precipitation, humidity and evaporation, surface run-off and river systems and rate of run-off are dealt with. Underground water is predominating supply in many localities owing to low rainfall, low run-off, and high evaporation. German "Grundschewelle" method of impounding water is much practised. Long after flood season, many sandy rivers carry water which slowly moves along rocky or impervious bed underneath, with little evaporation. Impervious wall of clay, concrete or masonry, having crest flush with, or below, sand surface, intercepts this water, which is extracted by sinking well.—*W. G. Carey.*

Water Purification by Ozone. Anon. Water and Water Engineering, 34: 408, 433, September 20, 1932. Experimental ozone plant has been constructed at works of Metropolitan Water Board (London) to treat 5,120 gallons (Imperial) per hour. Tests show that water 71.8 percent *B. coli*-positive in 1 cc. became after ozone treatment *B. coli*-negative in 100 cc. Earthy tastes are removed; but treatment is much more expensive than chlorination.—*W. G. Carey.*

A New Filter with Bactericidal Action. G. Lakhovsky. Comptes Rendus, 137–139, January 4, 1932. In experiments employing metal circuits in direct contact with water, effective sterilization of water infected with *B. coli* and *B. typhosus* was attained in 24 hours. This process sterilizes without filtering. Filtering candles are liable, in time, to pass toxic matter and microbes: but, by incorporating with procelain paste some silver chloride and firing at 1200°C. for 24 hours, porous candle containing finely divided silver was obtained which after 225 successive tests had not lost its sterilizing and filtering effect, filtrates remaining bactericidal for some days.—*W. G. Carey.*

The Law of Interstate Waters and Its Application to the Case of the Delaware River. Thaddeus Merriman. Jour. New Eng. W. W. Assoc., 45: 3, 199–266, September 1931. Traces development of Interstate Common Law from basic principles, fundamental justice, and common usage. While each state may adopt its own doctrine, disputes between states are settled by U. S. Supreme Court. Adjacent states may, with approval of Congress, adopt interstate Compacts. In July, 1927, City of New York filed plans for additional water supply to average 600 m.g.d. to be drawn, with appropriate reservoir construction, from five non-navigable tributaries of Delaware River lying wholly within State of New York. Release of water was to be permitted whenever natural flow fell below 0.45 second-feet per square mile of drainage area, and volume equal to ordinary flow was to be released every day from July 1 to November 1. Plans met the approval of Water Power and Control Commission of State of New York. In May, 1929, New Jersey filed Bill of Complaint in United States Supeme Court against N. Y. City and State, and Pennsylvania obtained permission to file statement of its interests and relief desired. New Jersey Bill listed 8 general particulars in which plan was claimed illegal and sought injunction perpetually restraining New York and all others from diverting, or abstracting, waters from Delaware River, or from any of its tributaries. Most important and appealing allegation of damage was in respect of oyster industry of Delaware Bay. Pennsylvania took more liberal attitude, seeking proper allocation of water and protection of low water flow of Delaware River. Recommendation of Special Master Burch was based on Pennsylvania plan, with diversion reduced to 440 m.g.d., and with provisions (1) that whenever flow of Delaware River at Port Jervis, or at Trenton, should fall below 0.50 second-feet per square mile of drainage area, water should then be released to increase the flow, but not to exceed 0.66 second-feet per square mile of drainage area; and (2) that sewage of Port Jervis should be treated to reduce organic impurity by 85 percent and *B. coli* content by 90 percent. Decision, presented in full in appendix, in general, follows recommendation of Special

Master. Ancient riparian doctrine was shown to be inapplicable to this case. —*Thos. F. Donahue.*

Diversion of Interstate Waters for Domestic Water Supply. Litigation and U. S. Supreme Court Decision in Case of Connecticut vs. Massachusetts. FRANK E. WINDSOR. Jour. New Eng. W. W. Assoc., 45: 3, 267–311, September 1931. Metropolitan Water District comprises 20 cities and towns located within ten miles of Massachusetts State House in City of Boston. Major portion of water supply has been from Wachusett Reservoir and involved diversion of Nashua River, which flows through New Hampshire. No question involving interstate water rights was raised thereby. In 1926–7 legislation was enacted to bring water to the Wachusett Reservoir from Ware and Swift Rivers, tributaries of the Chicopee, which in turn empties into the Connecticut, a navigable interstate river, which forms in its upper reaches the boundary between New Hampshire and Vermont and then flows across Massachusetts and Connecticut into Long Island Sound. It is navigable to Hartford, Conn. In December, 1927, Connecticut started legal proceedings to enjoin Massachusetts from making the diversion. Opinion of U. S. Supreme Court, rendered in February 1931, sustaining the master in all important particulars, dismissed Connecticut's Bill of Complaint and enabled Massachusetts to procure about 93 percent of the amount of the diversion contemplated by its legislature. Significant points, as affecting future takings for municipal water supplies, are recognition (1) of principle of equitable division of interstate waters, (2) of domestic consumption as the highest use of water, and (3) of right of any community to choose an unpolluted source in preference to one polluted.—*Thos. F. Donahue.*

The Development of Water Purification in New England. ROBERT SPURR WESTON. Jour. New Eng. W. W. Assoc., 45: 315–320, December, 1931. While development of modern artificial filtration plant dates from installation at Chelsea, England, in 1829, first filter adequately to express results of sanitary science was that built at Lawrence in 1893. This intermittent filter, operating on theory of sewage treatment by bio-chemical oxidation, is still functioning efficiently. Building of slow sand filters followed the Lawrence Experiment. First municipal mechanical filter was placed in service in Somerville, N. J., in 1885. Between 1895 and 1900, groundwork for modern rapid sand filtration was laid by GEO. W. FULLER at Louisville, by ALLEN HAZEN, and by others. Despite numerous advantages of rapid filtration many New England municipalities retain their slow sand plants. Slow sand filtration at Hartford, Conn., is very efficient. Providence and Cambridge have modern rapid sand plants. Chlorination for disinfection has lagged in New England, because long storage practised in most places was deemed adequate protection.—*Thos. F. Donahue.*

Operating Experiences at Cambridge, Massachusetts, Filtration Plant. MELLVILLE C. WHIPPLE and FRED E. SMITH. Jour. New Eng. W. W. Assoc., 45: 4, 321–333, December, 1931. Plant has nominal capacity of 14 m.g.d. Provision is made for pumping wash waters back to coagulation basin. Filter

effluent collects in flume, from which it discharges into aërator consisting of riffle plates studding a sloping surface. Lime for corrective treatment and chlorine are added at entrance to 3.5-m.g. clear water basin. In 1928, color of 70 p.p.m. in raw water was reduced by treatment with alum and sodium aluminate to average of from 5 to 10 p.p.m. *Synura* was eliminated from Stony Brook Reservoir with $CuSO_4$. Chlorine residual of from 0.05 to 0.1 p.p.m. is maintained without taste or odor. Red water trouble was decreased by use of soda ash, but rapid deterioration of brass piping at Harvard University led to substitution of lime. Tables of operating and cost data are included. Recently $800,000 has been appropriated for securing more water and enlarging purification facilities.—*Thos. F. Donahue.*

Five Years' Purification at Providence, R. I. Elwood L. Bean. Jour. New Eng. W. W. Assoc., 45: 4, 334–350, December, 1931. Scituate impounding reservoir has capacity of 37 billion gallons and discharge is regulated to maintain at definite level stream below the dam. Water from warm surface layers during summer unduly stimulates biological activity in coagulation basin and resulting gases lift sludge to surface: cooler, deeper levels must then be used. Variation in raw water has lessened so gradually that risk of future instability is believed to be precluded. Influent aëration makes a beauty spot and is valuable in destroying microörganisms and eliminating hydrogen sulphide. About 70 percent of carbon dioxide present is removed and dissolved oxygen content is increased. Alum dosage has been decreased to minimum of 0.45 grains per gallon. Optimum pH for coagulation lies between 5.8 and 6.2. Sand of effective size of 0.42 mm. gives good results; larger sizes are ineffective, due to high penetration of fine alum floc. This fineness affects backwashing; it is impossible to wash to a clear water. Although bacterial counts in raw water are low, ammonia-chlorine treatment has been given a trial in order to determine its effect upon distribution system. Water delivered to consumer is of good sanitary quality, soft, and almost colorless. Taste and odor occur very rarely. As many as 30,000 tests on the water from its source to consumer have been recorded in one year.—*Thos. F. Donahue.*

Operation of the Greenwich, Conn., Filter Plant. Harold C. Chandler. Jour. New Eng. W. W. Assoc., 45: 4, 351–359, December, 1931. Main sources of supply are Putnum and Rockwood Lakes. Communities served, Greenwich. Conn., and Rye and Port Chester, N. Y., have combined population of 70,000, Plant has capacity of 8 m.g.d. Aëration has proven effective for removal of gases; alum is used as coagulant, although sodium aluminate and chlorinated copperas have been experimented with; and water is chlorinated. Provision has been made for optional final aëration, for which water must be pumped 10 feet to aërators. Plant effluent is mixed with water from old pressure filters. Lime used for correcting corrosive properties of filtered water was also effective in removing manganese. Average cost of operation per million gallons, not including fixed charges, was $16.98 during third year of operation.—*Thos. F. Donahue.*

Water Filtration at Hartford, Conn. W. A. Gentner. Jour. New Eng. W.W. Assoc., 45: 4, 360–371, December, 1931. After long and exhaustive studies and experiments, slow sand filtration was decided upon, for which water from Nepaug and West Hartford Reservoirs is particularly well adapted, on account of its low color and turbidity. Local disapproval of chemicals, lower operating costs, and abundance of available land were also factors. Filtration was started in February, 1922, and has continued without interruption. There are 8 beds of ½ acre, and 2 of ¾ acre sand surface and filtered water basin of 15 m.g. capacity, including 6½ m.g. for normal reserve and 8½ m.g. to be held as fire reserve. Careful control has kept plant in efficient operation, producing safe water at low cost of $3.03 per m.g. Average daily consumption is 18.63 m.g.; average rate of filtration is 3.49 m.g.d. per acre, with maximum rate of 5.41. This will probably be increased with installation of mechanical washers, which have been recommended.—*Thos. F. Donahue.*

A Fresh-Water Reservoir in a Salt-Water Lake. Russel C. Fleining. Compressed Air Magazine, 37: 8, 3883, 3887, 3889, August 1932. Lack of fresh water in State of Utah is drawback to its development. Great Salt Lake is largest inland body of water west of Mississippi, covering 2000 square miles. It has no outlet except by evaporation and collects drainage of large basin through numerous rivers and smaller streams as well as subterraneously; principally on its eastern shore. This is fresh water. Proposal made many years ago by Ferdnand de Lesseps had been found feasible and engineering committee is now investigating project to enclose 146 square miles of eastern area by means of two dykes, 2.63 miles and 5.2 miles in length. With help of canals and inflowing streams, these dykes would form reservoir impounding supply estimated at 813,000 acre-feet annually with evaporation loss of 344,000 acre-feet. Dykes are to be equipped with submerged sluiceways having automatic one-way gates, so that as head of water is built up in reservoir, the salt water, being denser, will be forced out at bottom and displaced by fresh. On top of each dyke there are to be roadways. Cost has been figured at $750,000.—*R. H. Oppermann.*

A Note Concerning the Effect of a Specific Environment on the Characteristics and Viability of Several Strains of Aërobacter Aërogenes and Escherichia Coli. Walter L. Kulp. Jour. Bact., 24: 317–20, 1932. Pure cultures of *B. coli* and *B. aërogenes,* held for long periods in soil, showed no change in physiological, morphological, or cultural, characteristics.—*Edw. S. Hopkins.*

The Fermentation of α-Methyl-*d*-Glucoside by Members of the Coli-Aërogenes Group. Stewart A. Koser and Felix Saunders. Jour. Bact., 24: 267–72, 1932. New medium for separation of *B. aërogenes* and *B. coli* organisms was developed. It is *not* specific as regards separation of soil and fecal *B. coli.*—*Edw. S. Hopkins.*

Problems of Water Sterilization in the Tropics. H. Ruge. Arch. Schiffs- und Tropen-Hyg., 36: 208–214, April, 1932. Discusses sterilizing effect of very weak solutions of metals, especially of copper and of silver. Bactericidal

power of these metals is function of exposed surface. Ordinary water containing 15 p.p.m. of silver is completely sterile at end of from two to four hours. Power of sterilizing is also possessed by glass vessels in which such water has been stored, possibly because of some silver remaining attached. Following advantages are claimed for this process: (*a*) low cost, (*b*) negligible quantities of silver remain in solution, (*c*) expert operators not required, and (*d*) leaves no taste.—*R. DeL. French.*

The Bactericidal Action of Metals. A. J. Markvoort and K. T. Wieringa. Chem. Weekblad, 29: 242–247, April 16, 1932. Describes experiments carried out in Wageningen laboratories, which indicate strong bactericidal action of Katadyn silver, possibility of using same metal surface numerous times, though with decreasing effect, and fact that solution of the silver must precede any bactericidal action. Activity is increased in presence of oxygen and decreased in presence of hydrogen: it is most marked at 28°C.; at 3.5°C., it is greatly reduced. Very dilute solutions of silver nitrate (0.0000068 percent) are strongly bactericidal. *R. DeL. French.*

Hydrogen Ion Concentration in Mine Waters. H. Winter and H. Monnig. Glückauf, 58: 368–273, April 16, 1932. Results of analyses of numerous mine waters from Ruhr district of Germany. Attempt was made to connect pH value with corrosive effect on samples of iron, but without conclusive result. pH values ranged from 5.9 to 7.8.—*R. DeL. French.*

The Radioactivity of Potable Waters. Tarbouriech and Cassagne. Bull. Soc. Chem. de France, 51–52: 1107, September, 1932. Radioactivity appears to be confined to "mineral waters." Spring-water supply of Langogne (Lozère) showed 15.35 millimicrocuries of radium per liter, and that of Salvétat (Hèrault), 4.45 mmc. per liter. In both cases, waters come from granite and gneiss areas. Analyses were made with Chénevau-Laborde apparatus.—*R. DeL. French.*

Graphical Representation of the Composition of Water. R. Frey. Ann. de Chem. Anal., February 15, 1932. Salts dissolved may be plotted on rectangular co-ordinates, giving diagrams similar to Michel-Lévy diagrams for rocks, using quotients obtained by dividing respective weights of constituents present by corresponding molecular weights. Alkaline carbonates are plotted $+x$; carbonates of alkaline earths, $+y$: alkaline sulphates, $-x$; and sulphates of alkaline earths and chlorides, $-y$. From inspection of triangles thus obtained, suitability, or otherwise, for domestic or boiler use of water represented is immediately apparent.—*R. DeL. French.*

Water and Ice Supplies on Common Carriers. F. M. Brickenden and J. R. Menzies. Canadian Pub. Health J., 1931, 22: 570–73. From Bull. of Hygiene, 7: 4, 239, April 1932. Canadian Department of National Health has exercised control over water supplies of railway trains since 1930 and of vessels on Great Lakes since 1923. Water is supervised as to its sources, storage, and distribution, and is frequently analysed. In 1923 50 cases of typhoid fever among

seamen and passengers on the Great Lakes vessels were reported; but in 1929, only two. Diminution is credited to regulations in force.—*Arthur P. Miller.*

Chlorox as a Water Purifier. T. Banuelos. Monthly Bull. Philippine Health Serv., 1931, 11: 191–5. From Bull. of Hygiene, 7: 4, 239, April 1932. Phenol coefficient for "Chlorox," as tested against cholera, typhoid, and dysentery organisms, is claimed to be about 20. It is found satisfactory for heavily polluted waters.—*Arthur P. Miller.*

The Use of Activated Carbon in the Purification of Air and Water. R. Cambier. Ann. d'Hyg. Pub., Indust. et. Sociale, 1931, 9: 217–29. From Bull. of Hygiene, 7: 4, 239, April 1932. Methods of preparation of activated carbon, some forms of apparatus in which it may be used, and its use (1) as a taste remover in the purification of water and (2) as a bacterial filter are briefly discussed.—*Arthur P. Miller.*

On the Use of Seitz Filters for Freeing Water from Bacteria. J. K. Baars and W. M. A. Lecluse-Asselbergs. Meded. Dienst. d. Volksgezondheid in Nederl. Indie, 21: 7–14, 1932. From Bull. of Hygiene, 7: 8, 515, August 1932. At Water Purification Testing Station, Mangarai, Seitz EK filter with surface of 350 square centimeters was tested. Results were found to depend on numerical density of organisms and on amount of suspended matter. Filter soon becomes permeable to bacteria and is soon clogged by suspended matter with reduction in filtration rate. It is concluded that Seitz filter has only limited use for sterilizing clear water containing few organisms, and that even then, filter must be changed after four days, or apparatus sterilized each time before use. Filter is of little value for purifying water with suspended matter, or contaminated muddy water.—*Arthur P. Miller.*

Report of a Mild Epidemic of "Food Poisoning" by Ice at the Naval Air Station, Anacostia, D. C., and the Marine Barracks, Washington, D. C. A. T. Schwartz. U. S. Nav. M. Bull. 30: 141–2, 1932. From Bull. of Hygiene, 7: 8, 520, August 1932. Responsibility for this epidemic, involving 65 individuals, is imputed to ice; workman responsible for cleaning and handling wooden covers to freezing bath had been ill with similar infection about 7 days previously. Ice is stored only a short period before use.—*Arthur P. Miller.*

Lactose Fermenting Anaërobes in Soil and their Relation to Sanitary Water Analysis. C. E. Skinner and A. H. Baskin. Proc. Soc. Exp. Biol. and Med., 29: 551–4, 1932. From Bull. of Hygiene, 7: 8, 522, August 1932. Authors determined approximate numbers of lactose-fermenting anaërobes of *Cl. welchii* type in samples of soil from forests, peat bogs, and unmanured fields. By one method, approximate number of anaërobes per gram of soil varied from 6 to 5600; by another, from 2 to 10,000. Conclusion is that presence of anaerobes of this type in water cannot be regarded as evidence of fecal pollution.—*Arthur P. Miller.*

A New and Satisfactory Medium for the Isolation of B. Coli. G. Cascelli. Zentralblatt für Bakt. Parasitenkunde und Infektionskrankheiten. 124: 7-8, 537-38, June 1932. *B. coli* grows quickly and freely on cupriferous agar to form characteristic colonies, raised in center and with sharp edges: color in center is yellowish brown, paling outwards to yellow and to light yellow at periphery. For preparation of medium, 2 drops of 10 percent copper sulphate solution are added to 10 cc. liquid agar (alkaline), sterilized 20 minutes at 110°C., and poured onto plate.—*Manz.*

Pollution of Water Supplies, Especially of Underground Streams, by Chemical Wastes and by Garbage. A. Lang. Zeitschrift für Gesundheitstechnik und Städtehygiene, 24: 5, 174-82, May 1932. Author reports three cases in which it became necessary to abandon groundwater supplies on account of chemical contamination of wells caused respectively by (1) residues of wood-tar factory stored at distance of 197 feet, (2) wastes of picric acid works at several miles distance, and (3) waste pickling liquors. An old garbage dump situated about 1476 feet upstream from ground water wells increased total solids in ground water from 360 to 552 p.p.m. and hardness from 190 to 272 p.p.m. because of lixiviation and percolation by rainwater.—*Manz.*

Biological Removal of Phenols from Waters and Its Relation to Oxygen Demand and Bacterial Counts. A. Müller. Technisches Gemeindeblatt, 35: 12, 148-52, June 1932. In Berlin tap water and in water of river Spree phenol-absorbing bacteria are always present. The strains isolated probably belong to different kinds. Phenol reduction is always accompanied by heavy increase of bacterial counts and of biochemical oxygen demand. Attempts to increase phenol reduction by addition of nutrients have been as yet without result. Noxious influence upon streams of phenol-containing sewage even in very low concentrations is apparent from strongly increased oxygen demand. Biochemical oxygen demand in samples analyzed amounted to 1.62 parts for each part of phenol.—*Manz.*

The Use of Seamless Steel Socket Pipe for Water Mains. Schroeder. Technisches Gemeindeblatt, 35: 2, 13-16, January 1932. Questionnaire on this subject addressed by Prussian Ministry of Agriculture to 88 municipal authorities brought in 36 replies. Following statistical statement of advantages and disadvantages as reported, experiences favorable and otherwise in each individual case are discussed, including expert commentary on behalf of Pipe Association. Conclusions follow: (1) Before installation of steel pipe, iron-corroding properties of both soil and water must be carefully examined. (2) Use of steel pipe in aggressive soils is dangerous, nor does covering with inert soils assure complete protection if ground water, or percolating water, gains access to pipe. (3) Unavoidable damage to external protective coverings is to be carefully repaired. (4) For steel pipe, outside locations are preferable because local net work is too much exposed to corrosion. (5) As protective coverings, Herolith and Tornesit are recommended.—*Manz.*

Oxygen Consumed Test: Methods in Use Reviewed. Alfons Kaess. Archiv für Hygiene und Bakt., 107: 1, 42–66, October 1931. Two methods of heating are used in Germany, either (*a*) over open flame, or (*b*) in boiling water bath; and addition of KMnO is either (*a*) in cold, or (*b*) after heating to boiling. With boiling water bath, values in good agreement are obtained; while over open flame, differences up to 0.18 p.p.m. have been found. Over open flame, depending on whether heating was carried (*a*) just to the boil, or (*b*) to vigorous boil, differences up to 0.33 p.p.m. have been observed. Values obtained in boiling water bath are lower by about 0.30 p.p.m. than those over open flame. After 30 minutes in boiling water bath, same values are obtained as in 10 minutes over open flame. When $KMnO_4$ is added to boiling sample, then values 0.15 p.p.m. greater are obtained than when added in cold: difference is greater, the greater the content of organic matter. Determination of chlorine absorption in boiling water bath gave lower and more consistent results than over open flame. Author recommends period of 30 minutes in boiling water bath for oxygen consumed test.—*Manz.*

Private Water Supply and Sewage Disposal Problems. F. H. Kingsbury. The Commonhealth (Mass. Dept. of Public Health), 19: 3, 142. July-August-September, 1932. Although over 97 per cent of population of State reside in cities and towns provided with public supplies, there remain 127,000 people in Massachusetts dependent upon private supplies. Wells, or springs, should be protected against entrance of surface drainage and foreign matter. Dug wells, if constructed of stone, should be cemented water-tight from point 4 or 5 feet below ground level and should have water-tight curb extending from 1 to 1½ feet above same level. Ground in vicinity of well should at all times be free from pollution by seepage, whether from cesspools, sub-surface drains connected with septic tanks, earth vault privies, barnyard drainage, or other sources. Wells or springs may sometimes be polluted by tillage. It is important that lead pipe should not be used unless hazard of plumbo-solvency can be excluded. Untreated surface supplies for private use are not safe unless where long periods of storage and adequately protected watersheds are available. Suitable supply of ground water may almost always be obtained.—*G. C. Houser.*

Municipal Work Relief Projects. Health News (N. Y. States Dept. of Health), 9: 35, 141, August 29, 1932. Many sorely needed water supply and sewerage projects in New York State, postponed because of financing difficulties, are specially adapted for work relief, because of large proportion of labor entering into their construction, their long life, and lasting benefit to citizens. It is believed that over 200 municipalities in State could advantageously undertake such projects. Many improvements to existing public water supplies are, moreover, needed, for sake of increased protection, better physical quality of water, additional fire protection, or extensions to areas not now served.—*G. C. Houser.*

Education in Sanitation a Gradual Process. Health Bulletin (N. C. State Board of Health), 47: 10, 8, October, 1932. Bacteriologists, health officers,

and sanitary engineers have issued repeated warnings that safety of water can in no way be judged by its appearance. Many teachers in schools of State do not yet understand that clear and sparkling water flowing out of the hillside is not always pure; or how disease is spread. Diffusion of knowledge of sanitation is a gradual process; and, until it becomes universal, duty of public health forces is to continue their efforts every day in year.—*G. C. Houser.*

Safe but Unpalatable. J. C. KNOX. The Commonhealth (Mass. Dept. of Public Health), 19: 2, 97, April-May-June, 1932. Certain communities of greater Boston supplied with water from Spot Pond, a reservoir on Metropolitan system, complained of very disagreeable odor and taste. Microscopical examinations disclosed presence of *Uroglena, Synura, Dinobryon,* and *Asterionella.* These, while producing disagreeable conditions, have never been known to be injurious to health. Application to pond of copper sulphate, at rate of 2 pounds per m.g., destroyed more objectionable organisms within a few days. When taste first appeared, public abandoned the safe although unpalatable public supply and resorted to springs and wells, many of which had been unused for years and produced water of questionable quality.—*G. C. Houser.*

Public Health Administration as Applied to Sanitation in Monongalia County, W. Va. R. C. FARRIER and L. M. BOARD. Quarterly Bulletin, W. Va. State Dept. of Health, 20: 1, 27, January 1933. Safe and adequate water supply of city of Morgantown provides water also for 4 small towns adjacent and has within past year extended its mains through Scott's Run community to supply more than half its 6,000 inhabitants, effecting among them substantial decrease in typhoid case-rate. Town of Blacksville is likewise provided with safe and adequate supply from model plant in operation for more than 2 years. Approximately one-half of county's population is abundantly supplied with water which is regularly checked and tested by Health Department. Remaining population depends upon springs and wells.—*G. C. Houser.*